Rio Blanco Oil Shale Project

PROGRESS REPORT 10

GEOTECHNICAL DATA GATHERING PROJECT

HYDROLOGIC PROGRAM
SECTION 1.2
APPENDIX 1
Volume 1

To Area Oil Shale Supervisor
United States Geological Survey

by
Wright Water Engineers
for
Oil Corporation

dard Oil Company (Indiana)

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PROGRESS REPORT #10

APPENDIX INDEX

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SURFACE WATER
INVESTIGATIONS AND METHODS

PRECIPITATION

A comparison was made between storage and recording-type rain gaging stations. The purpose was to investigate regional trends, to provide a quantitative method of fitting in missing data, and to provide a quantitative assessment of comparing data between the two gage types. U.S.G.S. precipitation data collected from October 1974 through September 1976 were used. Rain gaging stations that were compared are located on Dry Fork, Corral Gulch, Box Elder Gulch, Cathedral Bluffs, Stake Springs Draw, and Yellow Creek. The comparison was made using standard least squares regression analysis.

The linear least squares fit of input data points (x,y) is calculated using the following:

$$\text{Slope} = m = \frac{\frac{\Sigma x \Sigma y}{n} - \Sigma xy}{\frac{(\Sigma x)^2}{n} - \Sigma x^2}$$

$$\text{Intercept} = b = \frac{\Sigma y - m\Sigma x}{n}$$

The y' for entered x and x' for entered y are calculated as follows:

$$y' = mx + b$$
$$x' = (y - b)/m$$

The coefficient of determination is calculated as:

$$r^2 = m\left(\frac{\Sigma x \Sigma y}{n} - \Sigma xy\right)/\left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)$$

The following is a matrix of the coefficient of determination for pairs of stations. The coefficient of determination is a measure of the proportion of variance in one variable predicted by variance in the other variable.

U.S.G.S. Station No.	6237	6235	6340	Cath*	6230	6255
6237 (S)	1	0.70	0.57	0.35	0.21	0.21
6235 (S)		1	0.52	0.07	0.15	0.14
6240 (S)			1	0.35	0.36	0.07
Cath* (R)				1	0.70	0.58
6230 (R)					1	0.77
6255 (R)						1

Note:
(S) = storage gage
(R) = recording gage
* Cathedral Bluffs Station

Results inidicate that a good trend correlation exists between Dry Fork and Corral Gulch stations, Cathedral Bluffs and Stake Springs Stations, and Stake Springs and Yellow Creek Stations. Poor correlation exists between storage and recording gage types.

STREAM MORPHOLOGY

Morphology of the streams in the Tract C-a area is controlled by geologic and climatic factors (Ivan J. Wymore, 1974). Most of the tract surface is composed of the Uinta Formation and its weathering products which are made up of brown to light-brown fine-grained massive sandstone with some siltstone (Amondo & Ivey, RBOSP). The light-gray canyon walls in the tract's major drainages are outcrops of the underlying Parachute Creek Member. The Upper Parachute Creek Member consists of light-gray marlstone with gray siltstone and fine-grained sandstone.

In the Piceance Basin, northwest facing slopes often show less erosion than south to southeast facing slopes. The south to southeast facing slopes often are more modified by greater exposure to climatological effects such as sunlight intensity than are opposite slopes (D.G. Frickel & others, 1975). A greater number of reentrants and erosional fans therefore occur along south to southeast facing slopes.

Stream and creek flows within the tract are ephemeral, while downstream of the tract flows become typically perennial. The difference between perennial and ephemeral flow is that the load-discharge ratio increases downstream in the ephemeral channel due to percolation losses (Chow, 1964). Ephemeral flow features in the tract point to a large variability in frequency and volume of discharge in gully channels. These features include trenchlike channel incisions that grade into smooth depressions. This contrast in downstream profile indicates that a dynamic relationship exists between sheet (diffuse) flow and channel flow. In this situation, channel erosion proceeds upstream while deposition fills up the gully mouth downstream.

CLASSIFICATION

Drainages within the Piceance Creek Basin have not been classified by the Colorado Water Quality Control Commission. White River has been areally classified based on the confluence with Piceance Creek. The White River and tributaries from its source near Trapper's Lake to the mouth of Piceance Creek is quality class B. The mainstem of White River from the mouth of Piceance Creek to the Colorado-Utah state line is quality class B_2.

Waters designated class B_1 or B_2 are waters suitable or to become suitable for all purposes for which raw water is customarily used, excluding primary contact recreation such as swimming and water skiing.

In class B_1 the dissolved oxygen concentration is not less than 6 milligrams per liter (mg/l), whereas in class B_2 dissolved oxygen concentration is not less than 5 mg/l. For class B_1 water, temperature is not increased above 68°F. by any means other than natural means, nor is temperature increased in streams and in the epilimnion of lakes or reservoirs more than 2°F. by any discharge. For class B_2 water, temperature is not increased above 90°F. by any means other than natural means, nor is temperature increased by discharges more than 5°F. in streams and more than 3°F. in epilimnion of lakes or reservoirs. Criteria for settable solids

floating solids, taste, odor, toxic materials, oil and grease, radioactive material, fecal coliform bacteria, pH, and fecal streptococcus are the same for B_1 and B_2 water.

BENEFICIAL USE

The probability that stream water within Tract C-a and Yellow Creek would exceed certain limits was investigated regarding the suitability for potable, range animal, and irrigation uses (Todd 1969, McKee and Wolf 1963). Generally accepted water quality limits and the probability that these limits will be exceeded at a particular location for a particular use were determined. Water quality limits could not be determined for agricultural purposes. The following are important factors in irrigation water quality:

Absolute limits to the permissible concentrations of salts in irrigation water cannot be fixed for several reasons:

a. It is almost universally true that the soils solution is at least three to eight times as concentrated as the water that replenishes it, because of the evaporation of water from the soil surface, transpiration by plants, and the selective absorption of salts by the plants.
b. There is apparently no definite relationship between the concentration and composition of the irrigation water and those of the soil solution, which in some cases may be as much as 100 times more concentrated than the water.
c. Plants vary widely in their tolerance of salinity, as well as of specific salt constituents.
d. Soil types, climatic conditions (such as temperature, rainfall, and humidity), and irrigation practices may all influence the reactions of the crop to the salt constituents.
e. Interrelationships between and among constituents may be highy significant; the effect of one ion may be

> modified by the presence of another. (Such synergistic influences operate between calcium and sodium; boron and nitrates; selenium and sulfates). Good drainage of the soil may be a more important factor for crop growth than the salts in the irrigation supply. (McKee & Wolf, 1963)

The water quality values for beneficial use on Box Elder Gulch West are based on samples taken during ephemeral flow during the snowmelt season. Water quality constituents that might limit the beneficial use for farmstead and potable use are Fe, pH, and TDS. A possible reason for high concentrations of these constituents is the nature of flow at this station. Spring snowmelt causes considerable erosion along channels, and surface leaching. High values of iron, pH, and TDS can be attributed to this type of flow along the upper reaches of Box Elder Gulch. Water quality for livestock beneficial use is within established suggested limits. Agriculture beneficial use cannot be determined due to unestablished synergistic soil influences.

The probability of a certain chemical constituent exceeding suggested water quality limits for Corral Gulch was determined. The reach of Corral Gulch in Tract C-a is ephemeral, with surface flow becoming subsurface flow just downstream of the Corral west gaging station. Perennial flow along Corral Gulch is recorded east of the tract at the Corral east gaging station. Beneficial use of Corral Gulch water for farmstead or potable use is limited by high values of TDS. Hardness becomes a limitation at the downstream Corral east station. To some extent, fluoride also could be a limitation at the Corral east station. The pH can be high at the Corral west station. Water quality for livestock beneficial use is within established suggested limits. Agriculture beneficial use cannot be determined due to unestablished synergistic soil influences.

The probability of a specific chemical constituent exceeding suggested water quality limits at Yellow Creek gaging station was determined.

Beneficial use of Yellow Creek water for farmstead and potable use could be limited due to high concentrations of Cd, Cr, Fl, Fe, pH, TDS, and hardness. The beneficial use of this water for range animals could be limited due to high fluoride values. Agriculture beneficial use cannot be determined due to unestablished synergistic soil influences.

Field crop tolerance to water quality in and surrounding Tract C-a can be broadly categorized according to conductivity. Reliable field crop categorization based on water quality requires more detailed soil chemical composition than is available in and surrounding Tract C-a. Detailed soil analysis is necessary to allow determination of possible synergistic reactions between soil and water. A conservative range of maximum conductivity values for most field crops is 4,000 to 10,000 umhos/cm (Todd 1969, pages 185-190). The field and forage crops this range applies to include: flax, corn, sorghum, rice, oats, wheat, rye, alfalfa, huban, strawberry clover, and yellow and white sweetclover. Maximum values of less than 4,000 umhos/cm have been reported from chemical analysis of samples taken from all stream gaging stations in and surrounding Tract C-a. The Yellow Creek near White River sampling site periodically has water showing specific conductance in excess of 4,000 umhos/cm.

To determine if the type of water is different at the Box Elder station as compared to other stations on Tract C-a, the proportional relationship between cations and anions was investigated using trilinear diagrams. Box Elder sampling site data were compared to the other Tract C-a stations during snowmelt periods. The snowmelt runoff periods were the only time during the year that flow was recorded at the Box Elder station. During such periods Box Elder type water could be distinguished from the Rinky Dink station by having less $Na + HCO_3$. There is some indication that during periods of intense snowmelt the type of water shifts to a more bicarbonate type along the ephemeral reaches of Box Elder and Rinky Dink Gulch. In general, however, Box Elder Gulch type water at the gaging station, which is above the reach that receives perennial spring flow, is slightly weighted toward carbonate hardness. In relation to other tract sampling sites, Box Elder type water is less weighted toward noncarbonate hardness.

The proportional relationship between major cations and anions of Corral Gulch water samples was investigated. These data suggest that little seasonal water quality type change occurrs within the major constituent proportions checked. Therefore, the type of water is very nearly the same throughout the year. The type of water between the Corral west and and the Corral east station is slightly different; Corral east is slightly more Na + HCO_3. In general, Corral Gulch type water is slightly weighted toward carbonate hardness with a gradual increase in carbonate hardness downstream. The type water along Corral Gulch in Tract C-a is overall slightly more weighted in Na + HCO_3 than at other gaging station sites on tract. The trilinear data suggest that there is little shift in the proportion of groundwater contribution downstream at the Corral east station as compared to the Corral west station. Generally, there is apparently no major seasonal shift in type water; little or no major seasonal change in the proportion of groundwater contribution could be determined. There is some evidence, however, that during periods of intense spring snowmelt the Corral east station type water changes to one in which no one cation-anion pair exceeds 50 percent.

The type of water at the Yellow Creek sampling station was investigated using trilinear diagrams. The Yellow Creek station water type is similar to the type water at Tract C-a in that weighting is toward HCO_3; however Ca is weighted more, and Na + HCO_3 less at Tract C-a stations. The overall type of water at Yellow Creek is one in which the water is near to being inordinately soft in proportion to the content of dissolved solids. Therefore, Yellow Creek water at the sampling station is considerably more Na + HCO_3 type than Tract C-a water. Trilinear type water analysis also suggests that there is little or no basic changes in water type with season. Therefore, these data indicate there is usually a constant proportion of groundwater contribution throughout the year at this station.

STATISTICS

Concentrations of chemical parameters in a natural stream system tend toward random variation due to the multiple sources of stream flow. There is, however some autocorrelation of concentrations with time. Stream flow on Tract C-a can be considered to be composed of the following sources:

1. snowmelt runoff
2. storm runoff
3. discrete groundwater discharge, and
4. diffuse groundwater discharge.

Each of these sources of streamflow contain geographic and time dependent variation in quality. In addition, the proportion of each of these contributions changes with time and is a function of prior conditions. Thus, the resulting surface water quality on a long-term basis can be treated as a nearly stochastic combination of the above four components. Probablistic determination of expected water quality based on data collected during the baseline monitoring program will allow projections of expected ranges in water quality in future years, assuming that the proportion of stream flow components acting during the sampling period are representative of long-term variations.

In order to estimate long-term expected concentration ranges in chemical parameters, it is necessary to choose a statistical model for the population of chemical concentrations in stream flow at a station. Histograms of numerous constituent concentrations were plotted and many showed a distinctive right skewness. When the data were plotted in log form the normal curve was more closely approximated. The tendancy of natural water quality toward a right skewed frequency distribution has been found by several other investigations (Chow, 1964; Hem, 1970; Klansman et al, 1976; U.S.G.S., 1975; Steele, 1972; Hitchon, et al, 1971) and the standard practice is to assume that the population of chemical concentrations is best described by the log-normal distribution.

The hypotheses that the frequency distributions are log-normal was tested using chi squared. This is a technique of objective comparison of shapes of the theoretical frequency distribution with one derived from observed

data. The derived frequency distributions were first determined using the method of moments, however, questionable results were obtained on some of the highly leptokurtic distributions.

Since the observed probability denisties did not always follow the ideal log-normal distribution, the method of nonlinear least squares, as described by Snyder (1972), was used to estimate the parameters (i.e. geometric mean and deviation) of the probability density function. This method minimizes the difference in the calculated probability density function from the observed histrogram of relative frequencies, and has the advantage that threshold values (reported as less than a sensitivity limit) can be incorporated without biasing the sample. The observed data were first transformed into normal form by taking the log to base 10 and constructing a histogram of this normalized data. Only pH and temperature were not transformed. The following probability function was fitted to the observed histogram (Snyder, 1972):

$$f(x) = \frac{NW}{\sigma(2\pi)^{1/2}} \quad \exp \quad -\frac{1}{2}\left(\frac{x-m}{o}\right)^2$$

where: N = number of observations
W = width of each frequency class on histograms
σ = standard deviation
x = mean of frequency class
m = mean of population
f(x) = expected number of samples in class

The function is fitted to the data over the range estimated to included 99 percent of the population rather than over the range of the samples. The equation following is brought to a minimum using nonlinear least squares:

$$E = \Sigma_1^n \left[N(x) - f(x)\right]^2$$

where: E is error term
N(x) is number of observations in class
f(x) is expected number of samples in class

An equation of the probability density function is then derived that can be used to predict the percentage of time a given parameter concentration will be less than or equal to that concentration.

Confidence limits on the mean value can be derived by using T values and degrees of freedom. The 95 percent confidence limits are presented on the summary printouts. Summary tables were prepared for all parameters at each station and best fit estimates of geometric means and geometric deviations, number of samples they were based on, confidence limits and points on the probability density curve, and are presented in Appendix 3. Chi squared goodness of fit statistics were derived and over one-half of the derived curves were acceptable using this criterion at the 5 percent confidence level. The distributions that did not meet this criterion were due to the fact that there was still some right skewness even after taking a log. The best fit log-normal distributions were retained as a best estimate for the tables, even though some of the heavy metals may fit one of the extremal type distributions. Analysis error in the determination of trace heavy metal concentrations may also modify the distribution. No data on the standard deviation of lab determination of heavy metal concentrations were available. Heavy metals usually show extreme variation due to possible controls by suspended sediment adsorption (Angino, et al 1969).

SEDIMENT

A study was made to determine initial baseline TDS and suspended solids of the watersheds in the surrounding Tract C-a. The purpose of this investigation was to define the rate of sediment loss due to stream erosion, to determine the relative contribution of suspended and dissolved solids from the different watersheds, and to find seasonal effects, if any, on TDS. Available U.S.G.S. data for water year 1975 were used. A linear relationship between TDS and conductivity was found to exist for a number of surface water chemical analyses. The relationship was found to have a confidence of 63 percent. Therefore, TDS values are derived values based on U.S.G.S. conductivity values. The rate of sediment transport

due to dissolved solids is obtained by the product of TDS and a corresponding flow value. The length, gradient, and orientation and size of discontinuous gullies, ungullied reaches, and alluvial fans are important factors that can affect sediment yield (Chow, 1964). Due to the variability of these factors in and about Tract C-a, substantial variation in daily sediment loads would be expected.

It has been reported that the annual Piceance Creek source area total sediment yields ranges from 0.3 to 0.7 acre-feet per square mile (D.F. Frickel, 1975). It is also reported that maximum annual channel erosion rates are about 0.36 acre-foot per square mile. It is further mentioned that Yellow Creek basin soils are less permeable and more erodible than most other areas in the Piceance Basin. Weeks (1974) reported that suspended sediment discharge measured from a station below Ryan Gulch averaged about 0.03 acre-feet per square mile. Maximum sediment discharges were noted during snowmelt periods for this station. Suspended sediment data that were collected in or near Tract C-a show a wide range of average values from the different stations. Suspended sediment loads in tons per day per square mile of drainage basin range from 0.02 to 0.17. These data were determined from instantaneous samples collected and analyzed by the U.S.G.S. A linear least squares fit of flow values versus corresponding sediment discharge was made. The regression analysis covered each month. The purpose of the investigation was to uncover a difference, due to seasonal changes, in sediment versus flow correlation. Good correlations were found to exist during snowmelt periods. During periods of high rainfall correlations were also good. During low flow periods, poor correlations existed. The linear least squares method with the data available was not able to distinguish a difference in snowmelt sediment discharge versus rainfall sediment discharge.

In order to determine the interrelationship of continuously recorded parameters, correlation and regression analyses were conducted. Correlations between flow sediment and conductivity at the four monitoring stations with continuous records were done. Scattergrams of log conductivity versus log flow for Tract C-a station were generated. The scattergrams for continuous data are shown in Appendix 4.

Correlations of flow with conductivity showed statistically significant relationships at Box Elder Gulch near west line of Tract C-a, Corral Gulch near east line of Tract C-a, and Yellow Creek near White River. No significant relationship between flow and conductivity was observed for Corral Gulch near west line of Tract C-a. The tract stations showed a trend of increasing conductivity with increasing flow. This suggests that surface runoff carries a dissolved solids load similar to or greater than the baseflow discharge. This relationship is reversed at Yellow Creek near White River in that high discharge events in general have a lower TDS concentration. This means that baseflow is generally higher in TDS concentration than surface runoff. This relationship is complicated by interaction of channel flow with increased discharge from the alluvium during falling stage following a runoff event.

All stations with simultaneous data on suspended sediment load and flow showed high correlations of increase in flow with increasing sediment load. Part of this correlation is due to the use of flow sediment concentration to yield a sediment load. In general, however, high flows are associated with high sediment concentrations. Tract stations generally show a threshold type of response in that a given flow must be exceeded before the sediment load exceeds 2 tons per day. The threshold for Corral Gulch near east line of Tract C-a appears to be about 1 cfs. Box Elder gulch near west line of Tract C-a shows a somewhat higher threshold of about 1.4 cfs. Part of the increase in sediment load probably is derived from channel erosion that takes place during high flow while the remainder is carried in by surface runoff during intense overland flow. Yellow Creek near White River does not show a threshold but rather a direct increase in sediment load with increased flow. This tends to suggest that channel erosion is less important in the lower part of Yellow Creek.

Corral Gulch near the east line of Tract C-a shows the best correlation between conductivity and suspended sediment load. In general, at this station high conductivity is an indicator of high suspended sediment load.

This indicates that surface runoff on Tract C-a carries a high dissolved solids load. Yellow Creek shows a poor negative correlation between suspended sediment load and conductivity. Box Elder Gulch shows no significant correlation between suspended sediment load and conductivity.

BOX ELDER GULCH

TDS was determined using both instantaneous data and continuous data. Instantaneous TDS was found by U.S.G.S. chemical analysis of conductivity. Synthesized TDS values were derived from conductivity. Sediment values in tons per day reached 4.58 during water year 1975. An average TDS value during snowmelt flow is 2.68 tons per day. For water year 1975, TDS amounted to 0.27 tons per day per square mile. For water year 1974, a similar value was also found. Since surface flows in 1976 were substantially lower than the previous two years, and cumulative TDS is a function of flow, it is not expected that the 0.27 tons per day per square mile of the Box Elder watershed determined for 1974 and 1975 is applicable for 1976. The 0.27 tons per day per square mile is about five times as great as TDS loads in other neighboring watersheds.

A linear regression fit was made between TDS and flow. The months where enough data existed for this analysis were May and June. The correlation coefficients (r) were 0.975 and 0.872 respectively. Therefore, a positive relationship exists between flow and TDS milligrams per litre for Box Elder Gulch during snowmelt periods.

Suspended sediment loads data for Box Elder Gulch are very limited. Data exist for the months of June, July and August in 1974. These data suggest that average suspended sediment loads are on the order of 0.17 tons per day per square mile. Maximum yearly values of TDS and suspended sediment occur in June. This is the period of peak snowmelt runoff.

TDS was determined using both instantaneous data and continuous data. Instantaneous TDS was found by U.S.G.S. chemical analysis. The results agree with synthesized TDS values derived from continuous conductivity data.

Sediment analyses for the two Corral Gulch stations have been occuring since mid-1974. Sediment load from TDS has reached 1.19 tons per day for the Corral west station. The average TDS load for this station of 0.46 tons per day. This represents about 0.05 tons per day per square mile of watershed above the gaging station. Values of TDS from the watershed above the Corral east of Tract C-a station also average 0.05 tons per day per square mile of watershed. TDS values for this station reach 4.13 tons per day during peak snowmelt runoff periods. The average TDS sediment load is 1.62 tons per day. This is consistent with the greater amount of flow that occurs at this station as compared to the upstream station.

TDS values that were obtained over a period from April through June of 1975 and were abnormally high for the Corral Gulch east station. This was due to pumping tests at core hole locations D-19 and D-18.

A linear regression fit was made between TDS and flow for the Corral east station. The results show that a good fit is obtained during periods of snowmelt runoff and during periods of heavy rainfall events. During periods of base flow, very little correlation existed. Months in which correlations of greater than 0.70 occurred were March through July, and September.

Suspended sediment data exist for water year 1975 for the Corral east of Tract C-a station. These data are from chemical analyses done on instantaneous samples taken by the U.S.G.S. The baseline average suspended sediment load is 2.60 tons per day. This amounts to 0.09 tons per day per square mile of watershed. This is considerably less than the sediment load per square mile of watershed on Box Elder Gulch.

A relationship of TDS in tons per day between the Corral east of Tract C-a station and a station on Yellow Creek can be made. A linear regression gave a correlation coefficient (r) of 0.71. Based on 1975, data increases in TDS over time appear to correlate for periods of snowmelt runoff and for major rainfall events.

On the basis of one analysis, Rinky Dink Gulch, TDS amounts to 0.05 tons per day per square mile of watershed. Though the amount of data is limited, the amount of TDS per square mile is in good agreement with Corral Gulch stations and the Yellow Creek station. Due to the meager flow, no further analysis was possible.

A water sample was collected during Feburary 1976 flow at Stake Springs Draw, and conductivity was measured on two days in March, 1976 at the U.S.G.S. station. The February sample showed a TDS load of 0.01 tons per day while the March values were estimated from conductivities to be 2.62 and 0.88 tons per day. No further analysis was attempted due to lack of data for this drainage.

TDS was determined using both instantaneous data and continuous data at the Yellow Creek station. Instantaneous TDS was determined by the U.S.G.S. from chemical analyses of grab samples from the station. These data agree well with synthesized TDS values derived from continuous conductivity data. Sediment data that are in final form were not available from the U.S.G.S for water year 1976. Sediment data collection has been occurring at this station since May 1974. Sediment load in TDS for water year 1975 reached a high of 20.75 tons per day. The average amount was 10.78 tons per day. This amounts to 0.04 tons per day per square mile of Yellow Creek watershed. This value is similar to values derived from stations in and surrounding Tract C-a.

The monthly relationship between TDS and flow was investigated by a linear regression. It was found that good correlation existed for the months of January, March, and April, May through July, and September for flows above 1.5 cfs. These data indicate that a significant relationship exists during most of the snowmelt runoff period and during the period of high rainfall.

Suspended sediment data for water year 1975 are complete. Average suspended sediment loads were 4.71 tons per day. This amounts to about

0.02 tons per day per square mile of Yellow Creek watershed. This is an order of magnitude less than average suspended sediment results from stations on or near Tract C-a. Suspended sediment values have ranged from 0.10 to over 14.93 tons per day. Maximum values of suspended sediment occur during periods of highest yearly flows, also when TDS is at a maximum.

Along White River near Piceance Creek, during early spring snowmelt runoff TDS reaches a peak level. Suspended solids concentration peak levels occur in May and June and are delayed from TDS high values by about a month. Temperature of White River is lowest in January and highest in July and August.

PLOTS OF CONDUCTIVITY VERSUS FLOW

Plots of 1976 U.S.G.S. surface gaging station conductivity and flow data were made. Weighted and nonweighted values were used. Weighted conductivity for an average day per month versus daily average flow was plotted. Calculated conductivity versus flow was plotted. Conductivity did not increase proportionately, or in any predictable manner as flow increased.

WHITE RIVER WATER CHEMISTRY

The change in reported water quality of White River below the confluence of Picenace and Yellow Creeks using U.S.G.S. water quality analysis for water year 1974 was compared to expected water quality change based on the proportion of additional quantity of water added by the tributary drainages, i.e.:

$$mg/l_{AC} + (\Delta \text{ flow} \times mg/l_{T}) = mg/l_{BC}$$

where mg/l_{AC} is concentration of constituent above confluence

mg/l_{BC} is concentration of constituent below confluence

mg/l_{T} is concentration of constituent in tributary

Δ flow is ratio of White River to tributary flow

The purpose of this comparison was to investigate the existence of chemical precipitation or other mechanisms other than simple chemical mixing.

DURATION CURVES

Duration curves for temperature, suspended sediment load, specific conductance, and discharge were developed for Corral Gulch near West line of Tract C-a, Box Elder Gulch near west line Tract C-a, Corral Gulch near east line Tract C-a, and Yellow Creek near White River. These curves are based on all available U.S.G.S. continuous data from March 1974 through the end of September 1976. Due to access and equipment problems U.S.G.S. was not able to present complete records for this period. Stations Dry Fork near west line of Tract C-a, Stake Springs Draw near confluence with Corral Gulch, and Rinky Dink Gulch near east line of Tract C-a showed only minor flows in response to snowmelt and had no more than about 10 days of flow for the period of record.

Flow duration curves for the four stations listed above with sufficient data were developed. Yellow Creek near White River show the highest sustained flow as would be expected since it has the largest drainage area. The median flow for the period considered is 1.62 cfs. The low flow portion of the curve shows a flattening of the slope that is characteristic of reaches that have well-sustained baseflows. The minimum flows to be expected at this station range from 0.23 to 0.30 cfs.

Corral Gulch near east line Tract C-a has also shown continuous flow since March 1974. Median flow at this station is 0.54 cfs with a sustained minimum baseflow of about 0.06 to 0.10 cfs. Corral Gulch near west line Tract C-a has a median flow of 0.16 cfs and has flows greater than 0.01 cfs only 80 percent of the time.

Box Elder Gulch flows only about 20 percent of the time in response to snowmelt or intense rain. Flow in Box Elder Gulch exceeds that in Corral west of the tract about 12 percent of the time. This is due to different

snowmelt patterns in the Box Elder drainage. The peak snowmelt in Box Elder occurs after that in the other gulches and has a shorter duration but greater flow rates.

Conductivity duration curves for Corral Gulch near west line Tract C-a, Box Elder Gulch near west line Tract C-a, Corral Gulch near east line Tract C-a, and Yellow Creek near White River were developed. Yellow Creek shows the highest conductivity of any of the stations at all points on the duration curve. This agrees with the results of previous investigations that suggest that base flow in the lower reach of Yellow Creek is sustained by groundwater discharge from the Parachute Creek Member of the Green River Formation. Groundwater in this unit is generally very high in TDS in the lower portions of the basin. The low conductivity end of the duration curves shows mainly the dilution effects of snowmelt or storm runoff on the high TDS base flow. The upper limit of conductance represents the probable value in baseflow discharge and is about 4,500 to 4,800 umhos/cm. Median conductivity for Yellow Creek is 3,600 umhos/cm.

Corral Gulch near east line Tract C-a generally has lower values of specific conductance. Relationships at this station are more complex in that several springs, in addition to diffuse groundwater discharge and surface runoff, supply the flow. The upper limit on conductance of the base flow at Corral Gulch near east line is 1,800 to 2,100 umhos/cm. The median conductivity at this station is 1,250 umhos/cm.

Corral Gulch near west line Tract C-a is lower in conductivity than Corral near east line. The lower limit approaches that of Corral east and is about 750 to 800 umhos/cm. The upper conductivity limit at Corral near west line is 1,350 umhos and the median line of Tract C-a shows the lowest conductivities of all the stations. This station is useful for estimating the general quality of snowmelt runoff as the two springs in this basin are about 2 miles above the gaging station. Conductivities at this station range from about 600 to 800 umhos/cm.

The median conductivity value for Box Elder Gulch near the west line Tract C-a is 780 umhos/cm.

Mean daily temperature duration curves for Yellow Creek near White River, Corral Gulch near east line Tract C-a, Box Elder Gulch near west line Tract C-a, and Corral Gulch near west line Tract C-a are shown. Yellow Creek near the White River shows a median mean daily temperature of 14°C. Temperatures during the winter can fall to near 0°C. and this is probably due to diffuse groundwater discharge that cools rapidly in a short flow distance. There is also a component of low temperature flow in the stream above the gage. The maximum mean daily temperatures during the summer do not exceed 25°C.

Corral Gulch near the east line of Tract C-a shows a much flatter slope on the temperature distribution than Yellow Creek. The minimum mean daily temperature is about 5°C even during the winter, which suggests that a large portion of the flow passing this station is derived from a nearby source of groundwater. The median temperature is about 10.5°C which also suggests a nearby groundwater source.

Corral Gulch near the west line of Tract C-a shows a median temperature of 15.5°C, the highest of all the stations. This is due in part to the lack of flow during the winter months. The great temperature fluctuations suggest that groundwater discharge has time to equilibrate with the atmosphere before it reaches the gaging station.

Box Elder Gulch near west line of Tract C-a has a median temperature of 11°C. during times when it flows. The distribution is similar to Corral Gulch east of Tract but is not strictly comparable due to the ephemeral nature of the flow at Box Elder.

STREAM RECESSION ANALYSIS

Exponential curve fits were made on selected 1974 through 1976 hydrograph data supplied by the U.S.G.S.. The following algorithm was used:

Given a set of data points:

$$\{(x_i, y_i), i = 1, 2, \ldots, n\} \qquad y_i > 0$$

This program finds the least-squares fit for an exponential function of the form:

$$y = ae^{bx} \ (a > 0)$$

The problem is computed according to the linear equation

$$\ln y = \ln a + bx$$

Statistical outputs:

1. Coefficients a, b

$$a = \exp\left[\frac{\Sigma \ln y_i}{n} - b\frac{\Sigma x_i}{n}\right]$$

$$b = \frac{\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}}{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}$$

Note: n is positive integer $\neq 1$.

2. Correlation coefficient

$$r^2 = \frac{\left[\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}\right]^2}{\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}\right]\left[\Sigma (\ln y_i)^2 - \frac{(\Sigma \ln y_i)^2}{n}\right]}$$

3. Estimated value for x' given y

$$x' = \frac{1}{b}\ln\left(\frac{y}{a}\right)$$

4. Estimated value for y' given x

$$y' = ae^{bx}$$

"To forcast runoff from snowmelt, an analysis may be made of snowmelt hydrographs ... This analysis is based upon field experience in observing watershed runoff from snowmelt... Practically all snowmelt runoff enters stream channels as subsurface or groundwater flow, or usually as a combination of both. It may be reasoned, therefore, that the hydrograph recession toward the end of the snowmelt season should apply to each day's snowmelt contribution to the total flow. The total flow is essentially the summation of the daily contributions of flow through porous media according to the Darey law rather than the summation of overland hydraulic flows.

The recession factor can be used to derive the recession portion of the hydrograph.... The recession portions of the hydrograph are extended by lines having slopes which

"are computed from the recession factor for the corresponding discharge at the trough of the hydrograph. These straight lines can be extended to the base flow. A given day's contribution therefore consists of two areas: area 1, which is the volume of the day's snowmelt runoff appearing between troughs of two successive days, and area 2, which is the recession flow. These areas can be computed mathematically on the basis of the following equation originally proposed by Barnes:

$$Q = Q_o K_r^{\,t}$$

where Q is the flow in cfs at time t in days, Q_o is the flow in cfs at the beginning of the computation period or at t = 0, and K_r is the daily-runoff recession coefficient.

The above equation has been restated by W.T. Moody as

$$Q = Q_o e^{-kt}$$

where e is the base of natural logarithms, and k is a factor related to Barnes' K_r by $k = -1nK_r$," Handbook of Applied Hydrology, Chow.

Continuous surface flow can be divided into two components: a flow due to surface runoff and a base flow that is contributed by ground water. Since the time of gage installation in and surrounding Tract C-a, most runoff has been due to snowmelt.

A hydrogrpah response to a runoff event basically shows a rapid rise in water level followed by an exponential decline in water level. Many times the hydrograph response to a rainfall event is slightly different in that a greater amount of runoff is absorbed into the ground and therefore, a peak flow is somewhat delayed. During the initial phases of a water level rise indicated by a hydrograph, snowmelt freeze and thaw periods can often be distinguished.

The way in which a particular stream or reach of a stream responds to a runoff event can often be typified. This is done by fitting a mathematical expression to the normal pattern of the hydrograph recession curve. This has been done with available hydrograph data for Tract C-a. A recession analysis commonly adds some degree of predictability to stream flow. This is done by using the derived mathematical expression to provide estimated values (flow) for a given time. An indicator of the rate of recession for a particular stream is the exponent of the exponential recession relationship. It is called a recession constant. Typically, it has a declining value as flow recession proceeds, that is, the rate of flow recession declines with time.

Flow recession is a function of initial flow at the start of recession, and of time. Certain factors can strongly influence the recession constant. The degree of soil saturation, freeze and thaw conditions, permeability of the soil and stream bottoms, are some of the influencing factors. "A study of the infiltration rates of selected sites in the Piceance basin (J.R. Neinan, 1974) found that the soil covered ridges and bottom lands had infiltration rates ranging from 5 to 10 cm per hour for durations of one hour." (Weeks, 1974).

Base flows were determined by reviewing historical hydrographs and picking a flow that has been continuously maintained. This method is commonly called the cut off or scalping method. The percent deviation of yearly total runoff volumes to selected stations in White River Basin, Colorado for long-term mean flows is shown.

Stream recession analysis provided some degree of quantification of Box Elder stream flow. Two periods were used. The recession of flow after snowmelt for water years 1974 and 1975 are very similar in that recession occurs very rapidly. 1976 flow recession occurred much more gradually. May 16 through June 9 represents a snowmelt recession period, as does the period from June 25 through July 3.

A least squares fit was made for an exponential function of the form:

$$Q = qe^{-kt}$$

where Q is the initial flow value

t is time since recession started in days

k is related to the recession constant by K= 1nk,

Q is the particular value of flow at time t

(Garstka, Love, Goodall, 1958). For the period May 16 through June 9, the two equations

$$Q = 0.899e^{-0.083t} \quad \text{and} \quad Q = 0.534e^{-0.223t}$$

best fit the recession hydrograph data. The first relation best fits initial flow recession from 0.899 cfs down to 0.534 cfs. The second relation best fits flow recession from 0.534 cfs down to base flow. Recession constants for the two periods are in order, 0.92 and 0.81. Correlation coefficients for the best fits were respectively 0.96 and 0.86. For the period June 25 through July 3, the best fit relation is

$$Q = 0.680e^{-0.191t}$$

The recession constant is 0.84. The correlation coefficient for the fit is 0.98. The difference between the same flow periods for the two time periods is 15 percent.

Stream recession analysis also provided some degree of quantification of Corral Gulch stream flows. A stream recession analysis was done for the upper reach of Corral Gulch, the west line Tract C-a station, and for the watershed area reflected by the east of Tract C-a station. A least squares fit was made for an exponential function of the form

$$Q = qe^{-kt}$$

where q is the initial flow value

t is the time since recession started in days

k is related to the recession constant by K = -1nk,

Q is the particular value of flow at time t.

The upper station recession values were more susceptible to freezing and thawing periods during early snowmelt runoff due to the small amount of flows. Two periods of analysis represent early snowmelt runoff times for the upper station, April 9 through April 13, and April 13 through April 29. The best fit relationships that were derived for these periods are

$$Q = 0.48e^{-0.271t} \quad \text{and} \quad Q = 0.28e^{-0.153t}.$$

Corresponding recession constants are 0.76 and 0.85.

Recession occurs very fast in response to sudden thaw periods. When the main recession period occurred at the upper Corral Gulch station in response to snowmelt runoff, different recession relationships were found. For the two periods of July 5 through July 14 and July 30 through August 7, the following equations were best fit:

$$Q = 0.24e^{-0.092t} \quad \text{and} \quad Q = 0.41e^{-0.074t}.$$

Corresponding recession constants were 0.91 and 0.93. Correlation coefficients for the best fit were greater than 0.97. These recession values indicate a much more gradual recession period than occurred earlier in the season.

The Corral Gulch east of Tract C-a station had recession relationships that were similar to the Corral Gulch west of the tract station for July and August. Recession periods for the Corral east station were March 3 through March 10, May 30 through July 4, August 1 through August 10, and August 11 through August 24. The recession relationships derived for these periods were respectively:

$$Q = 0.49e^{-0.070t}, \quad Q = 0.65e^{-0.090t}, \quad Q = 1.15e^{-0.074t}, \text{ and}$$

$$Q = 0.92e^{-0.052t}.$$

Corresponding recession constants are 0.93, 0.91, 0.93, and 0.95. All of the least squares fits had better than 0.90 correlation coefficients. From these data it seems that recession flows are similar for different time periods at the Corral east of Tract C-a station.

A Yellow Creek flow recession analysis was done for the period March 20 through July 15 for water year 1976. A least squares fit was made for the exponential function of the form.

$$Q = qe^{-kt}$$

where q represents the initial flow value

t is the time since recession started in days

k is related to the recession constant by K = 1nk

Q is the particular value of flow at time t.

The relation derived was

$$Q = 3.35e^{-kt}$$

where k ranges from -0.041 to -0.139.

The recession constants range from 0.87 to 0.96. The value of the correlation coefficient for the best fit curve is 0.880. This station shows a longer recession time than the stations nearer Tract C-a.

FACTOR ANALYSIS

The structure of the correlation matrix of chemical parameters is very complex and difficult to interpret. It is desirable to find out which of the chemical parameters tend to be correlated as a group against other chemical parameters in order to make interpretations of source and mechanism for dissolution of dissolved chemical constituents. In order to do this, it is necessary to apply a technique known as factor analysis that attempts to simplify the information contained in correlation matrix into weighted combinations of variables or factors. The correlation coefficient matrix is generally a measure of how much of the individual variance of each constituent can be explained by relationships with each of the other constituents. The relative magnitudes of each of these constituents is unimportant since a correlation matrix looks only at variances and can be considered a covariance matrix on standardized variables.

Factor analysis is used to redistribute the explained variance present in the correlation coefficient matrix into a set of factors that are linear combinations of the original variables. Each of the factors is made up of proportions of the individual constituents in the form:

$$F_i = A_{i1} X_1 + A_{i2} X_2 \cdots + A_{ij} X_j$$

where F_i is factor i

Xj is the jth variable in standardized form

A_{ij} are constants derived in the factoring process

The method of factor analysis used in the study derived principal components (eigenvectors) from the correlation matrix, then proceeded with rotation of the principal components to derive the final factors. The Statistical Package for Social Sciences (SPSS) subroutine FACTOR was used for this analysis. In general, the objective of this method of factor analysis is to derive a set of synthetic variables that maximize the amount of covariance accounted for by a factor in the fewest number of original variables. This will yield a set of synthetic variables that are orthagonal, or noncorrelated, with the other factors. The amount of contribution of each of the original variables in standardized form to the rotated factors is measured by the loading of that particular component within a given factor. The loading coefficients are normalized to the range of -1 to 1 where the higher the loading, the more that particular component contributes to the given factor. Variables that are highly correlated as a group tend to have a high absolute value of the loadings with any given factor. Less important variables have loadings near 0. The explained covariance of factor is given by the eigenvalue and this is shown with the factor matrix. In general, the first factor will have the highest eigenvalue and account for most of the explained covariance in a correlation matrix, with successive factors accounting for less and less of the variance accounted for in that factor.

All chemical analyses from Corral Gulch near West Line Tract C-a, Box Elder Gulch near West Line Tract C-a, and Corral Gulch near East Line Tract C-a were pooled for the factor analysis. Two subsets of parameters were analyzed, the first of which included Ca, Mg, Na, K, Cl, SO_4, AlK, pH, and specific conductance. Two factors were extracted and rotated using the varimax criterion from the principal components matrix. The resulting communalities, factor loadings, and eigenvalues are given.

The first factor, which accounts for 74 percent of the covariance in the data set is composed of Na, Cl, K, and conductivity. This first factor probably represents groundwater contributions to streamflow. The second factor results from Ca and Mg, and SO_4 accounts for the remaining convariance. Together these two factors account for 70 percent of the variance in the data set with the remaining 30 percent being due to random variation unaccounted for by the two extracted factors. Factor scores were calculated and plotted on hydrographs to aid in interpretaton.

The value of the factor score is a relative index of the importance of that factor in accounting for the variance. Factor 1 is highly loaded on parameters that are abundant in groundwater due to dissolution of nacholite and very minor amounts of halite. The response of the hydrograph of Factor 2 to various streamflows suggests that the highly soluble components in the factor increase during summer storm events are possibly due to surface washoff or interflow discharge. During April through June 1975, during the aquifer testing program on C-a, Factor 1 showed the highest values of the baseline period. Anomalous low values of factor score 1 occurred during the snowmelt period of water year 1974. More gradual increases were observed during the snowmelt period of water year 1976. Drilling discharge effects also show up during 1974. During base flow periods the value of Factor 1 remains relatively stable, reflecting the input of deep groundwater discharge. Based on the analysis of the factor scores it is very difficult to separate the surface washoff effects from that of groundwater discharge. This conclusion agrees with that based on the analysis of continuous specific conductance data. Part of the reason for this is the excellent interconnection of Corral Gulch with the alluvium in the lower reaches on C-a.

Factor score 2 at Corral Gulch east of Tract C-a generally parallels the trend of factor score 1 during periods of baseflow; however, during snowmelt or storm runoff periods, there is an inverse relationship. The exception to this was the last phase of snowmelt during water year 1974. Factor score 2 generally reaches a high prior to beginning of

snowmelt, shows low and variable values during snowmelt and storm periods, and shows gradual recovery to highs during the summer and fall.

Factor 2 represents the interaction with water in the alluvium. There are several possible reasons for this grouping of parameters in Factor 2. The association of Ca, Mg, and SO_4 suggests that dissolution of minor gypsum or anhydrite may play a role. The more likely explanation, however, is that springs and diffuse seepage areas in the upper reaches of the Corral Basin supply water to underflow in the alluvium that undergoes concentration of dissolved solids by phreatophytic evapotranspiration. Dilution of this water in transient storage within the alluvium takes place during snowmelt or intense summer storms when sodium carbonate type waters infiltrate the alluvium. This is reflected in lower values for Factor 2 after the snowmelt season with the rise taking place during summer and fall due to draining of the alluvium and contribution of a greater portion of Ca, Mg, and SO_4 rich waters. There is some suggestion that the Ca concentration may be controlled by equilibrium with solids in that there is a moderate inverse relationship between Ca and pH.

A second factor analysis was completed on the combined tract station data base using a larger subset of chemical parameters. The results on the major constituents remain the same as the first factor analysis, however, in Factor 1, B and F showed high positive correlations with Na, K, HCO_3, Cl, and conductivity. N and NH_4 is moderately loaded in this factor and shows high inverse correlation with the oxidized nitrogen species.

The first factor again represents a combination ground water interflow and surface washoff mechanism. B and F are very highly associated with groundwater near Tract C-a and suggest major contributions of deep groundwater in this factor. During periods when surface washoff is active, overland flow is the dominant mechanism of water contribution to the stream and dilutes all other sources. In this surface washoff oxidized nitrogen species are carried to the stream and infiltrate the alluvium. During other times with little washoff oxidized nitrogen species undergo reduction

within soils and alluvium and are discharged to the stream. There is complexity in the mechanism in that the alluvial aquifer undergoes a transition from an oxidizing environment during late spring and summer to a reduction environment during fall and winter. Based on the second factor analysis it appears that the alluvium interaction may play some role in Factor 1, however, it is mainly controlled by groundwater and interflow moving into the alluvium.

Factor 2 remained about the same as in the first analysis except that manganese (Mn) was moderately loaded in this factor. The interpretation of this factor remains the same as before in that spring and seep water from the upper reaches interacting with the alluvium contribute to this factor.

Factor score 3 is loaded on pH, zinc (Zn), and lithium (Li) with negative loadings on F and B. This factor when plotted generally follows the trend of factor score 1 and is at its highest point generally during late spring and summer. The remaining factors showed loadings mainly on the heavy metals and unique interpretations were not attempted. It is likely that variances of the heavy metals are more controlled by redox, pH and dissolved oxygen interactions in the alluvium than anything else.

The dominant controls on surface water quality variation are the source and mechanism of discharge. During most of the year gulches on tract that show flow are due to emergence of groundwater from the alluvium where subsurface flow within the alluvium is restricted. Several springs supply flow to reaches but these flows rapidly infiltrate the alluvium. During periods of intense surface runoff, the water in the alluvium is somewhat diluted. At the end of the surface runoff period discharge from the alluvium is somewhat increased. An additional seasonal variation in alluvial groundwater is the concentration of solids by evapotranspiration during the summer.

CONDUCTIVITY VERSUS TOTAL DISSOLVED SOLIDS

The relationship between conductivity and TDS was investigated using least squares linear regression. U.S.G.S. surface water analysis data were used from the initiation of surface sampling on Tract C-a. This included data from gaging stations 0930, 6240, 6241, 6244, 6246, 6248, 6250, 6235, 6230, and 6242.. Available data from October 1974 through July 1976 were used. The least suqare linear regression algorithm data were generated by a desk mini-computer. The slope of the best fit line is 0.70; the correlation coefficient of .627 resulted. These results allow a fairly accurate estimate of TDS given conductivity, and conversely.

ALLUVIAL AQUIFER
INVESTIGATIONS AND METHODS

ALLUVIAL AQUIFER - DISCUSSION

Alluvial characteristics that were measured at the time of sampling of each monitoring hole were water level, temperature, specific conductance, and pH.

A histogram of 1976 water level data shows that S-7 and S-8 had low levels of saturation throughout most of the year. This implies that a stable water source was not available to these alluvial reaches and that recharge was of short duration and seasonal in nature. S-11 and S-12 had most frequent levels that were mid between their water year maximum and minimum. Therefore, a substantial amount of recharge to these aquifers is due to springs, but the seasonal snowmelt still effects these reaches to a large degree. By contrast, S-24 was generally highly saturated and did not respond as much to seasonal effects, because of a high proportion of continuous subsurface recharge.

A correlation matrix helps to show the time relationship of the water in the different alluviums. The matrices show that S-7 and S-11 are most highly associated, which would be expected since they are on the same drainage. S-8 and S-11 are also closely associated since S-8 is in a major tributary to S-11. Since groundwater flow is not a major contributor to saturation of the alluvium at S-8, the correlation between S-8 and S-11 is due to increased recharge from snowmelt and streamflow during similar periods. Also, discharge of water from these alluviums are not substantially different. Slight correlation exists between S-24 and S-8, and S-12 and S-11. It is expected that the spring snowmelt is the main reason for the correlation between these stations. The result that S-11 and S-24 are poorly related is due to the stable saturation of these alluviums and slight random water level variation cause poor mathematical correlation.

The time correlation between S-7 and S-8, by being negative, shows that the occurance of recharge with associated discharge is different for the two stations. This difference in initial response to snowmelt is attributed to differences in exposure and orientation of the drainage.

If the two alluviums are best correlated without regard to time a correlation of better than 0.70 is possible. This shows that the nature of the response and discharge due to snowmelt is very similar, without respect to time.

A comparison of the recession curves in the alluvial aquifers at S-7, S-8, and S-11 indicate that during years in which the temperature transition from winter to spring is rapid, less recession similarity exists between these aquifers and the rate of discharge is less than years that have early freeze and thaw periods. Early freeze and thaw periods allow increased percolation of snowmelt which smooth out the effects that can be caused by local topography during periods of rapid runoff. This is particularly true for an alluvium that is near dry prior to recharge, such as at S-7 during 1976.

Temperature of the alluvial water during the year follows similar patterns over the vicinity of the tract. During periods of highest temperature of the alluvial water, pH often reaches a peak shortly after the peak temperature. This period generally corresponds to minimum saturation in the alluvium.

ALLUVIAL AQUIFER RECESSION

Selected alluvial hydrograph data were fitted to exponential curves to investigate alluvial groundwater recession patterns. Hydrograph data were selected from those holes which showed good hydrograph recession trends after spring snowmelt during water years 1975 and 1976. The algorithm used for the exponential curve fit the least squares fit for an exponential function of the form:

$$y = ae^{bx} \quad (a>0)$$

The problem is computed according to the linear equation

$$\ln y = \ln a + bx$$

Statistical outputs:

1. Coefficients a, b

$$a = \exp\left[\frac{\Sigma \ln y_i}{n} - b\frac{\Sigma x_i}{n}\right]$$

$$b = \frac{\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}}{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}$$

Note: n is positive integer $\neq 1$.

2. Correlation coefficient

$$r^2 = \frac{\left[\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}\right]^2}{\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}\right]\left[\Sigma (\ln y_i)^2 - \frac{(\Sigma \ln y_i)^2}{n}\right]}$$

3. Estimated value for x' given y

$$x' = \frac{1}{b}\ln\left(\frac{y}{a}\right)$$

4. Estimated value for y' given x

$$y' = ae^{bx}$$

RECESSION EXPONENTIAL CURVES

Well No.	1975	1976
S-7	$Y = 21e^{0.0016t}$	$Y = 17e^{0.0033t}$
S-8	$Y = 26e^{0.0027t}$	$Y = 29e^{0.0032t}$
S-11	$Y = 40e^{0.0007t}$	

Note: Y is the depth
t is the time in days

Correlation coefficients for these fits are respectively 0.79, 0.93, 0.94, 0.80 and 0.99.

ALLUVIAL - FIELD PARAMETERS

A linear regression analysis was done using instantaneous water level and conductivity data collected during 1975 and 1976. The purpose of comparing these parameters over different stations was to try and associate the periods of the seasonal trends. The following algorithm for linear regression was used.

$$\text{Slope} = m = \frac{\frac{\Sigma x \Sigma y}{n} - \Sigma xy}{\frac{(\Sigma x)^2}{n} - \Sigma x^2}$$

$$\text{Intercept} = b = \frac{\Sigma y - m\Sigma x}{n}$$

The y' for entered x and x' for entered y are calculated as follows:

$$y' = mx - b$$
$$x' = (y - b)/m$$

The coefficient of determination is calculated as:

$$r^2 = m\left(\frac{\Sigma x \Sigma y}{n} - \Sigma xy\right) \Big/ \left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)$$

The following correlation coefficient (r) matrices were determined:

1976 WATER YEAR

Station	S-7	S-8	S-11	S-12	S-24
S-7		-0.26	-0.72	0.01	-0.02
S-8			0.26	0.26	0.18
S-11				0.06	0.11
S-12					0.16
S-24					

1975

Station	S-7	S-8	S-11	S-12
S-7		0.04	0.02	0.81
S-8			0.84	0.12
S-11				0.13
S-12				

The following correlation coefficient (r) matrix for conductivity was determined:

1976

Station	S-7	S-8	S-11	S-12	S-24
S-7		0.55	0.82	0.25	0.23
S-8			0.61	0.48	0.59
S-11				0.09	0.15
S-12					0.71
S-24					

Interpretation of these results is described in the two year Baseline Report.

SPRINGS AND DEEP AQUIFER INVESTIGATIONS AND METHODS

SPRING WATER QUALITY ANALYSIS

A comparison of the major group of chemical constituents Ca, Mg, Na, SiO_2, SO_2, Cl, and certain ratios of these constituents was made between the analyses of the following sources of aquifer water: alluvial, upper, spring, and perched; from 1975 Industrial Laboratory and NUS data. The purpose of statistical treatment of comparing these constituents within these groups was to quantitatively associate spring water with a specific source.

The following ANOVA alogrithm was used to compare the variance of the alluvial, upper, spring and punched aquifer groups.

One way analysis of variance is a technique for testing the differences between the population means of k treatment groups, where each group $i(i = 1, 2, \ldots, k)$ consists of n_i observations $x_{ij}(j = 1, 2, \ldots, n_i)$. The different groups need not have the same number of observations.

Formulas used:

$$\text{Sum of observations in group } i = \sum_{j=1}^{n_i} x_{ij}$$

$$\text{Total Sum of Squares} = SS = \sum_{i=1}^{k}\sum_{j=1}^{n_i} x_{ij}^2 - \frac{\left(\sum_{i=1}^{k}\sum_{j=1}^{n_i} x_{ij}\right)^2}{\sum_{i=1}^{k} n_i}$$

$$\text{Treatment Sum of Squares} = TSS = \sum_{i=1}^{k} \frac{\left(\sum_{j=1}^{n_i} x_{ij}\right)^2}{n_i} - \frac{\left(\sum_{i=1}^{k}\sum_{j=1}^{n_i} x_{ij}\right)^2}{\sum_{i=1}^{k} n_i}$$

$$\text{Error Sum of Squares} = ESS = SS - TSS$$

The value of the F statistic is:

$$F = \frac{DF_2 \times TSS}{DF_1 \times ESS}$$

Where: DF_1 = Treatment degrees of freedom $= k - 1$

DF_2 = Error degrees of freedom $= \sum_{i=1}^{k} n_i - k$

The algorithm used to calculate the t statistics was:

This program evaluates the t statistic

$$t = \frac{\bar{x} - \bar{y} - \Delta}{\left(\frac{1}{n_x} + \frac{1}{n_y}\right)^{1/2}\left(\frac{\Sigma x_i^2 - n_x\bar{x}^2 + \Sigma y_j^2 - n_y\bar{y}^2}{n_x + n_y - 2}\right)^{1/2}}$$

with $n_x + n_y - 2$ degrees of freedom, to test the significance of the difference (Δ) between the means (unknown) of two independent random samples from two normally distributed populations having the same unknown variance.

Given the sample:

$$x_i = [x_1, x_2, \ldots, x_{n_x}]$$

$$y_j = [y_1, y_2, \ldots, y_{n_y}]$$

then $$\bar{x} = \frac{1}{n_x}\sum_{i=1}^{n_x} x_i$$

$$\bar{y} = \frac{1}{n_y}\sum_{j=1}^{n_y} y_j$$

SPRING FLOWS

A statistical investigation was made of spring flow velocities as measured with a pygmy type water current meter by NUS personnel. Data were collected on about a quarterly basis over a two-year period, 1975 and 1976. The statistical investigation was made to try and group types of springs on the basis of flow.

The linear least-squares fit of input data points (x,y) is calculated using the following:

$$\text{Slope} = m = \frac{\frac{\Sigma x \Sigma y}{n} - \Sigma xy}{\frac{(\Sigma x)^2}{n} - \Sigma x^2}$$

$$\text{Intercept} = b = \frac{\Sigma y - m\Sigma x}{n}$$

The y' for entered x and x' for entered y are calculated as follows:

$$y' = mx + b$$

$$x' = (y - b)/m$$

The coefficient of determination is calculated as:

$$r^2 = m\left(\frac{\Sigma x \Sigma y}{n} - \Sigma xy\right) \Big/ \left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)$$

The following correlation matrix was generated. NUS designated surface velocity sampling sites.

NUS designated spring velocity sites	1	2	3	4	5	8	9	13	14	15	17	18	20
1		0.77	0.13	0.01	0.06	0.01	0	0.10	0.15	0.04	0.08	0	0.24
2			0.26	0.01	0	0.16	0.01	0.22	0.01	0.03	0.08	0	0.40
3				0.35	0.04	0.04	0.01	0.17	0.37	0.07	0.02	0.09	0.18
4					0.15	0.05	0.07	0.03	0.23	0.02	0	0	0.23
5						0.07	0.15	0.04	0.34	0.21	0.31	0.11	0.02
8							0.02	0.80	0.03	0.05	0.01	0.13	0.28
9								0.02	0.38	0.01	0.02	0.03	0.02
13									0.02	0.07	0.03	0.03	0.44
14										0.03	0.01	0	0.02
15											0.80	0.75	0.13
17												0.67	0.14
18													0.07
20													

To describe the result in terms of probability, the (t) distribution was evaluated:

The t distribution is evaluated by the following series expansion:

$$A(t|\nu) = \frac{2}{\pi}\left\{\theta + \sin\theta\left[\cos\theta + \frac{2}{3}\cos^3\theta + \ldots + \frac{2\cdot4\ \ldots\ (\nu-3)}{1\cdot3\ \ldots\ (\nu-2)}\cos^{\nu-2}\theta\right]\right\}$$

for $\nu > 1$ and odd

$$A(t|\nu) = \frac{2\theta}{\pi} \qquad \text{for } \nu = 1$$

$$A(t|\nu) = \sin\theta\left[1 + \frac{1}{2}\cos^2\theta + \frac{1\cdot3}{2\cdot4}\cos^4\theta + \ldots + \frac{1\cdot3\cdot5\ \ldots\ (\nu-3)}{2\cdot4\cdot6\ \ldots\ (\nu-2)}\cos^{\nu-2}\theta\right]$$

for ν even

Where: ν is the degrees of freedom

$t > 0$

$$\theta = \tan^{-1}\frac{t}{\sqrt{\nu}}$$

Then:

$$F = \frac{A(t|\nu) + 1}{2}$$

The results from these tests were inconclusive.

SPRING WATER QUALITY TYPE

To classify a spring within a particular range of water types exhibited by all springs near or on Tract C-a a histogram was constructed for each major constituent, United States Geological Survey and NUS water quality analysis results were used.

The histogram algorithm was:

$$\text{Class Interval (Cell No.)} = \text{INT}\left[\left(12\frac{x_i - x_{min}}{x_{max} - x_{min}}\right) + 0.5\right]$$

n = total number of x_i entered within the range specified

$$m = \text{mean value of the } x_i = \frac{\Sigma x_i}{n}$$

$$\sigma^2 = \text{variance of the } x_i = \frac{1}{n}\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}\right]$$

$$f_j = \text{frequency of class interval (cell) } j = \frac{N_j}{n}$$

where N_j = number of items in cell j

$$U_j = \text{upper limit of cell } j = \left(\frac{x_{max} - x_{min}}{12}\right)j + x_{min}$$

The results grouped NUS designated springs 1, 2, 3, 4, and 5 into three groups: 1 and 2, 3 and 4, and 5. That is, water types for these three groups appeared distinctive.

The obvious associations that can be made are: 1 and 2, 8 and 13, 15 and 17 and 18, and 13 and 20.

Station	Location
1	Cross Gulch Headwaters approximately 3,200 meters (2 miles) above the confluence with Spruce Gulch. This is the lowest of the three springs in the area. This station is located at the highest elevation of all the stations. All of the seepages in the vicinity of this station have been tapped for use in livestock watering. Nearby aspen trees appear to contribute a substantial amount of organic matter in the form of dead leaves to the seepages.
2	Spruce Gulch Headwaters approximately 1,500 meters (1 mile) above its confluence with Cross Gulch. This station is located approximately 50 meters downstream from the seepage area. The spring at the headwaters of Spruce Gulch appears to be a sulfur spring since the odor of H_2S is very evident and the bottom of the stream appears to be covered with an unidentified fungus.
3	Corral Gulch Headwaters approximately 50 meters from Maverick Spring.
4	Water Gulch Headwaters approximately 1,500 meters (1 mile) above its confluence with Corral Gulch. This station is located about 50 meters below the seepage area.
5	Headwaters Area of Stake Springs Draw. This station is located in a marshy area approximately 8,000 meters (5 miles) above the confluence with Corral Gulch. This headwaters area consists of a series of seeps which form a marshy area with extensive aquatic vegetation.
8	Box Elder Gulch (just after entering Tract C-a) approximately 1,200 meters (0.80 mile) below the USGS gaging station. This station is located about 50 meters below the seepage area.
9	Corral Gulch approximately 200 meters below its confluence with Water Gulch. This station is located on a small swift stream which has a gravel substrate.

13 The USGS gaging station on Corral Gulch just as it leaves Tract C-a.

14 Corral Gulch just after leaving Tract C-a. This station is located at a pond approximately 1,200 meters (0.8 mile) above 84 Ranch. Station 14 is located on a small pond which contains extensive mats of the aquatic plant Zannichellia palustris.

15 Corral Gulch approximately 100 meters upstream from its confluence with Stake Springs Draw.

17 Stake Springs Draw approximately 100 meters upstream of its confluence with Corral Gulch.

18 Yellow Creek approximately 100 meters downstream from the confluence of Corral Gulch and Stake Springs Draw.

20 Yellow Creek at the USGS gaging station near the White River.

SPRINGS

In order to determine the source of spring water discharging near Tract C-a, a review of the geologic structure and stratigraphy, water quality, and piezometric heads has been made. The springs studied in detail are those listed by NUS as Station Nos. 1, 2, 3, 4, and 8. The springs monitored by the United States Geologic Survey were also evaluated, although on a cursory level.

Utilizing available data regarding faults and other geologic structures, an attempt has been made to determine the source of the spring water.

The stratigraphy of the area is somewhat more indicative of the potential sources of the water. Methodology utilized to arrive at some broad conclusions were based upon published structure contour maps of the area. The NUS monitored springs were plotted on a contour map and the structure contours superimposed on these sites.

Upon analyzing the elevations of the sites and the structure contours, it can be noted that a similarity exists between the elevations of the top of the Mahogany Zone and the elevations of the springs. See Table 1 for elevation comparisons.

TABLE I

ELEVATION OF SPRINGS AND THE TOP OF THE MAHOGANY ZONE

NUS Spring No.	Approximate Surface Elevation	Elevation of the Top of the Mahogany
1	7,260	7,500
2	7,360	7,300
3	7,200	7,250
4	7,200	7,250
8	6,950	7,000

As can be noted, the elevations do not correlate exactly. The structure contour map is constructed using 100 foot contour intervals. The springs have not been surveyed and, therefore, the elevations were taken from a contour map reflecting 20 feet contour intervals. In light of the vertical control used, the corresponding similarities in elevations of both the emittance points of the springs and the top of the Mahogany Zone indicate a potential relationship.

The elevation of the NUS-monitored springs were also compared to the piezometric heads in the upper and lower aquifers. Again, the vertical control data preclude accurate analysis, however, some general observations can be made. Table II lists the correlating elevations.

As can be noted, the elevations of the piezometric heads in the lower aquifer are considerably lower than the spring elevations listed in Table I. The monitoring wells are located downgradient of the springs, nevertheless, indicate elevation differences of about 980 to 1,000 feet.

The upper aquifer piezometric head indicates a closer relationship between pressure head in the monitor wells and the springs. A variance of about 800 feet can be noted, however, the pressure gradient between the springs and source of the wells is about 800 feet. Therefore, a correlation can be made.

TABLE II

WATER SURFACE ELEVATIONS

Monitor Well No.	Surface Level	Upper Aquifer Average Water Level Elevation Oct. 1975 through August 1976	Lower Aquifer Average Water Level Elevation Oct. 1975 through August 1976
CE708	6917.86	6869.28	6642.50
CE707	7181.91	6928.57	6610.60
CE702	6656.30	6603.35	6611.96
GS-1	7247.00	7002.56	6645.01
AM-3	6924.00	6892.29	6609.17

A review of water quality of the springs, alluvial aquifer, and bedrock aquifers has resulted in additional general conclusions.

A total of ten chemical constituents, common to both the NUS springs and the USGS and Wright Water Engineers sampling programs, were reviewed. Table . lists a general range of the constituents from samples taken during the period August 1975 through March 1976.

TABLE III

GENERAL RANGE OF CHEMICAL CONCENTRATIONS
(in mg/liter)

Chemical Constituent	NUS Springs	Alluvial Aquifer	Bedrock Aquifers	
			Upper Aquifer	Lower Aquifer
Ca	43-107	90-140	33-105	8.2-19
Cl	3.8-17	6.7-21	7-14	5.6-34
Hardness	369-538	410-500	250-390	92-85
Mg	42-110	26-57	31-62	14-34
NO_3-N	.2-1.5	2.2-3.7	.1-.3	.1-.4
PO_4-P	.01-.25	.1	.1	.1
SiO_2	18.5-23.5	29-31	15-41	3-18
SO_4	87-316	190-280	185-370	55-235
Na	42-115	90-113	32-290	185-400
K	1.1-3.1	0	0-2.5	0-3.3

The table illustrates a considerable difference in chemical constituents in the springs and the lower bedrock aquifer.

This is not the case upon comparison of the NUS springs with the upper bedrock aquifer and the alluvial aquifers. The relationship in quality from these three sources is quite similar; however, the upper bedrock aquifer water quality appears to be more closely related to the springs than the alluvial water.

A cursory review of the water quality of the springs monitored by the USGS in the basin was also undertaken. The results of the review are similar to that of the NUS springs; of the constituents reviewed, a similarity exists between the quality in the upper aquifer and the springs as well as between the springs and the alluvial aquifers. No definite large variation was noted in the water quality.

UPPER AQUIFER RECOVERY

Several of the prelease exploration holes on and near the tract were left open so that a direct path existed between the two deep oil shale aquifer. Estimates of the rate of flow between the aquifer were available from interpretation of spinner logs. Most holes that had multiple runs of the spinner logs showed a decrease in flow with time. An estimate of the average flow is about 50 gpm in each hole. Several of the holes were open for periods of up to two years. The estimated total flow between the two aquifers is about 5,000 acre-feet from the upper aquifer into the lower aquifer. When the holes were completed in October and November of 1974 and the aquifers isolated, recovery began in both the upper and lower aquifers.

Since there was little information on a wide aerial basis on the upper aquifer transmissivity,estimates of this parameter were made using the method of objective function minimization. Several assumptions were made in order to simplify the analysis of transmissivity including the following: (1) 11 wells, AM-2A, AM3, CE 701, CE 702, CE 705A, CE 707, CE 708, CE 709, TO-1, TO-2, and TO-3 showed average downward flows of 50 gpm for 2 years

prior to shut in, (2) transmissivities and storage coefficients were constant. An interference type analytical model using the Theis equation was constructed and calibrated against observed drawdowns in GS 2-3, GS 12, GS 11 and GS 15. The calibration was done against the gradient over time in order to minimize the effects of the storage coefficient. The optimum transmissivity and storage coefficients found was T=3,000 gpd/ft and (s) = .001. All values were corrected for recovery effects using standard methods. A second estimate of T and S was made using the data for 1 year from GS 2-3 and the results agree with those listed above.

SEASONAL VARIATION IN UPPER AQUIFER WATER LEVELS

There is a suggestion from examination of upper aquifer water level hydrographs that a seasonal component of water level fluctuation is present. This is most apparent in the hydrographs of GS 9 and CE 708. The period on the seasonal variation is about 1 year while the amplitude varies from 5 to 10 feet. The high occurs during the winter and a 40 day lag exists between highs at GS 9 and CE 708. It appears that this seasonal variation may be due to recharge waves moving through the upper aquifer. The variations are present in other upper aquifer monitoring holes, however, they are not as apparent on visual examination. Trend analysis was completed fitting an exponential curve to the data to correct for the overall recovery of the aquifer and residuals from the trend were examined. In general the highs were during the winter with lows during the summer. A table of the slopes of the best fit lines to recovery data over the last year of the baseline is given in Table IV.

TABLE IV

SLOPE ON BEST FIT EXPONENTIAL CURVE

FOR UPPER AQUIFER WATER LEVELS

Monitor Hole Identification	Slope (Feet/Log-Cycle)
AM 2A	-36.97
AM 3	- 6.63
CE 702	6.98
CE 707	-28.46
CE 708	-11.60
CE 709	-11.96
G-S 1	-10.83
G-S 2-3	17.44
G-S 4-5	- 7.87
G-S 6	- 1.51
G-S 10	- 2.46
G-S 11	-15.76
G-S 12	-17.77
G-S 13	1.51
G-S 15	- 6.96
G-S M-1	1.99
TO-1	9.23
TO-2	-15.96

LOWER AQUIFER WATER LEVEL RECOVERIES AND SEASONAL TRENDS

Water level hydrographs for the lower aquifer were plotted and the graphs are presented in a following appendix. A consistent trend of exponential type recovery was observed on most of the plots. In order to quantify this exponential recovery, a least square line was fitted to the observed data and the results of this in terms of the slope of this line are shown on Table V. Residuals from this line were plotted and consistent residuals were detected. The residual tended to be positive during the winter. This may be in part due to transmitted of stress from the upper aquifer or due to leakage.

TABLE V

SLOPE ON BEST FIT EXPONENTIAL LINE
FOR LOWER AQUIFER WATER LEVEL RECOVERY

Monitor Hole Identification	Slope (Feet/Log-Cycle Time)
AM 2A	76.3
AM 3	69.4
CE 702	64.2
CE 707	53.6
CE 708	78.6
CE 709	71.6
G-S 1	- 1.21
G-S 2-3	68.2
G-S 4-5	54.8
G-S 6	70.6
G-S 9	48.8
G-S 10	61.8
G-S 11	66.4
G-S 12	77.2
G-S 13	70.8
G-S 15	74.8
G-S M-1	81.4
TO-1	72.3
TO-2	70.0

LOWER AQUIFER WATER LEVEL TREND

The lower aquifer appeared to exhibit a very regular exponential trend of declining water level. To see how regular this water level trend was, a predicted aquifer water level trend was generated and compared with the observed water level trend based on data collected on a monthly basis from November 20, 1975 to November 14, 1976. An exponential least squares fit was made on water level data from each hole to derive a predicted curve. The algorithm has been described elsewhere in this section. The predicted trend when compared to the observed trend, generally indicated

close agreement, although local differences occur. This is attributed to the fact that the lower aquifer response to interconnection was near complete during the latter part of 1976 and other mechanisms are becoming more apparent that are affecting water levels.

LOWER AQUIFER - RECOVERY CURVE FIT

The possibility of small seasonal water level fluctuations in the aquifer was investigated by comparing the residual values between a predicted water level trend and the observed water level trend. Since the deep aquifers were interconnected for a period of time, the primary water level trend in both aquifers was an exponential type due to recovery from interconnection. The algorithm for the predicted curve is similar to:

The problem is computed according to the linear equation

$$\ln y = \ln a + bx$$

Statistical outputs:

1. Coefficients a, b

$$a = \exp\left[\frac{\Sigma \ln y_i}{n} - b\frac{\Sigma x_i}{n}\right]$$

$$b = \frac{\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}}{\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}}$$

Note: n is positive integer $\neq 1$.

2. Correlation coefficient

$$r^2 = \frac{\left[\Sigma x_i \ln y_i - \frac{\Sigma x_i \Sigma \ln y_i}{n}\right]^2}{\left[\Sigma x_i^2 - \frac{(\Sigma x_i)^2}{n}\right]\left[\Sigma (\ln y_i)^2 - \frac{(\Sigma \ln y_i)^2}{n}\right]}$$

3. Estimated value for x' given y

$$x' = \frac{1}{b}\ln\left(\frac{y}{a}\right)$$

4. Estimated value for y' given x

$$y' = ae^{bx}$$

The results indicated that in most cases a seasonal fluctuation was present. Monthly water level data were used from November 20, 1975 to November 14, 1976.

UPPER AQUIFER - RECOVERY CURVE FIT

The cyclic water level trends in upper aquifer holes was investigated by comparing the residual values between the predicted and observed water level trends. The algorithm used to generate a predicted curve is shown

in the corresponding deep aquifer description. Water level data were used from November 20, 1975 to November 14, 1976. Correlation matrices were generated to compare the similarity of the cyclic trends between holes. The algorithm for the coefficient of determination matrix is:

The linear least-squares fit of input data points (x,y) is calculated using the following:

$$\text{Slope} = m = \frac{\frac{\Sigma x \Sigma y}{n} - \Sigma xy}{\frac{(\Sigma x)^2}{n} - \Sigma x^2}$$

$$\text{Intercept} = b = \frac{\Sigma y - m\Sigma x}{n}$$

The y' for entered x and x' for entered y are calculated as follows:

$$y' = mx + b$$

$$x' = (y - b)/m$$

The coefficient of determination is calculated as:

$$r^2 = m\left(\frac{\Sigma x \Sigma y}{n} - \Sigma xy\right) \Big/ \left(\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right)$$

Measured Water Level Matrix

Hole No.	1	708	3	6	9
GS-1		0.89	0.69	0.46	0.09
CE708			0.80	0.13	0.13
AM3				0.04	0.06
GS-9					0.28
GS-6					

Residual Water Level Matrix

Hole No.	1	708	3	9	6
GS-1		0.80	0.60	0.64	0.28
CE708			0.40	0.43	0.54
AM3				0.35	0.26
GS-9					0.35
GS-6					

These matrices show that residual water levels have better correlation, implying that the cycle trends have pretty much of the same period.

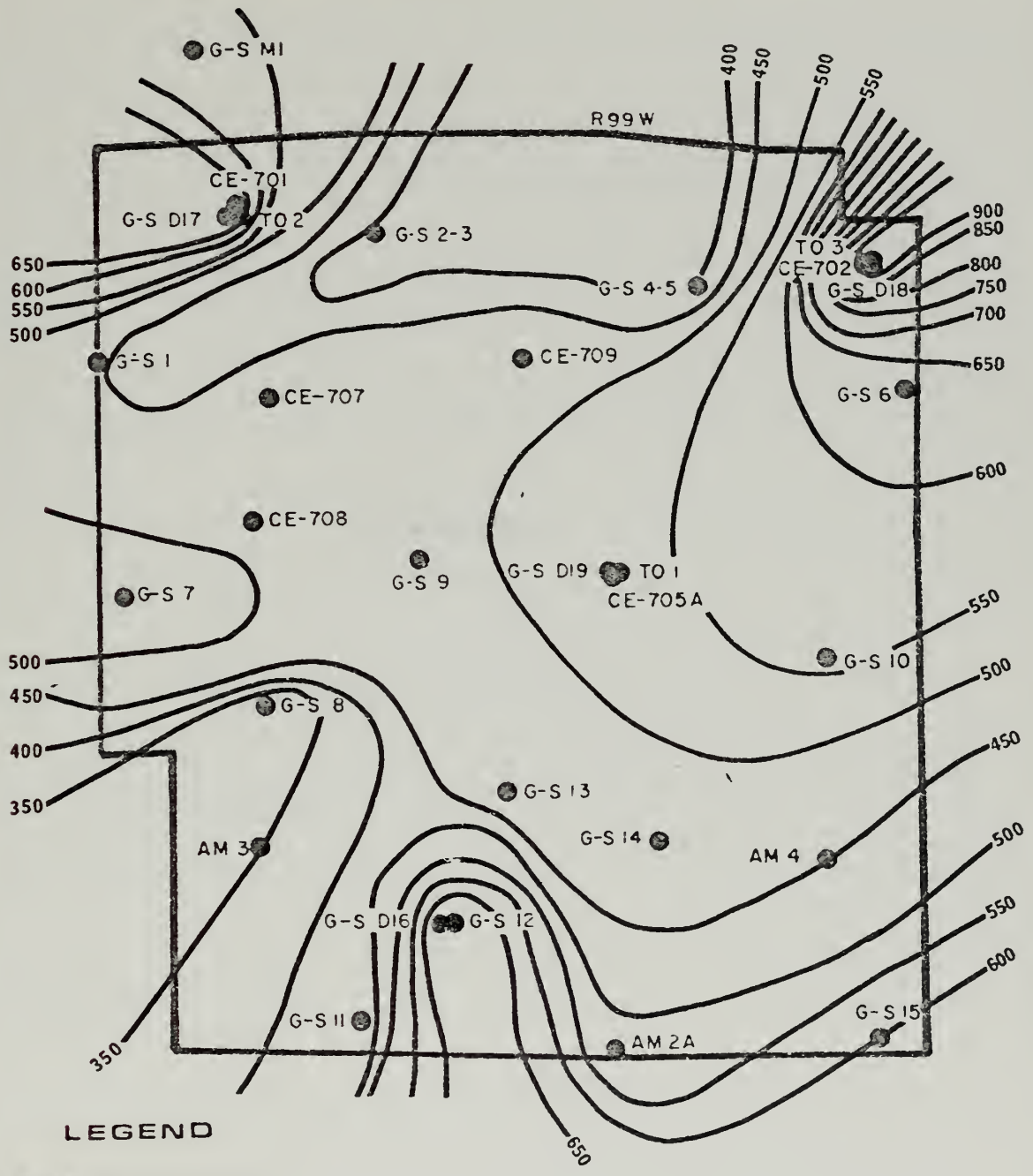
TRILINEAR DIAGRAMS

Many groundwaters can be characterized by the relationship of three cations (calcium (Ca), magnesium (Mg), and the alkali metals), and three anions (sulfate (SO_4), chloride (Cl), and bicarbonate (HCO_3), and carbonate (CO_3)). Trilinear diagrams have been extensively used to discriminate distinct groundwater types (Chow 1964; Walton 1970). To demonstrate that groundwater is a mixture of two other dissimilar types, a grouping of the mixture samples must lie between groupings of the parent sources if nothing is precipitated.

A general comparison was made of water quality of springs and seeps with alluvial water, upper aquifer water, and lower aquifer water by comparing plotting position on triangular diagrams (Walton, 1970). A selective sampling of United States Geological Survey (U.S.G.S.) and Wright Water Engineers chemical analysis data collected in 1975 and 1976 was used. Springs generally had less sodium (Na) and potassium (K) and greater proportions of Ca and Mg than in either upper or lower aquifer water. Lower aquifer water was relatively high in Na and HCO_3. Upper aquifer water showed scattered plotting position, possibly due to mixing with lower aquifer water. In general, upper aquifer Na + K percents were higher than spring and seep water but considerably lower than lower aquifer results.

It is apparent that spring and seep percent reactance values follow much more closely upper aquifer values than lower aquifer values. The comparison between spring and seep percent reactance values with alluvial values showed close similarity. Based on the accuracy of this method, it would appear alluvial water and most spring and seep water showed the same percent reactance values for Na + K versus Ca + Mg and SO_4 + Cl versus CO_3 + HCO_3, where no one cation-anion pair exceeded 50 percent. These results indicate that spring and seep water is likely to be a mixture of alluvial and upper aquifer water.

ISOPACH OF THE AQUITARD



LEGEND

TRACT OUTLINE

DRILL HOLES

CONTOUR INTERVAL 50 FEET

N

SCALE: 1" = 3000'

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BIBLIOGRAPHY TO APPENDICES

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GEOTECHNICAL DATA GATHERING PROJECT

HYDROLOGIC PROGRAM
SECTION 1.2
APPENDIX 2
Volume 1

To Area Oil Shale Supervisor
United States Geological Survey

INDEX

APPENDIX 2

1. ANOVA

2. CONTINUOUS HYDROLOGIC DATA SUMMARY STATISTICS

3. PERCENT EQUIVALENT PPM OF MAJOR GROUNDWATER CHEMICAL CONSTITUENTS

4. EXPONENTIAL CURVE FIT TO LOWER AQUIFER WATER LEVEL DATA

5. HISTOGRAMS, GROUNDWATER CHEMICAL CONSTITUENTS

6. SURFACE WATER, INSTANTANEOUS TOTAL DISSOLVED SOLIDS VERSUS CONDUCTIVITY LINEAR REGRESSION

ANOVA

Oneway analysis of variance was conducted to test the hypothesis that there was no difference at the 5 percent confidence level between chemical concentrations in samples collected during the pumping tests and those collected during the monitoring program. Sulfate and fluoride were the only constituents that showed a significant difference between methods.

The hypothesis that there is a difference between concentration of major constituents between the 3 aquifers. Potassium is the only constituent that does not exhibit differences between the 3 aquifers.

VARIABLE POTASS
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.1994	.1994	.755	.386
WITHIN GROUPS	133	35.0982	.2639		
TOTAL	134	35.2975			

VARIABLE SODIUM
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	9.2408	9.2408	135.959	0
WITHIN GROUPS	415	28.2066	.0680		
TOTAL	416	37.4473			

VARIABLE CHLORIDE
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	5.3015	5.3015	21.184	.000
WITHIN GROUPS	415	103.8569	.2503		
TOTAL	416	109.1584			

VARIABLE CALCIUM
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	22.0009	22.0009	107.992	0
WITHIN GROUPS	415	84.5466	.2037		
TOTAL	416	106.5476			

VARIABLE COND
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	2.2823	2.2823	54.099	.000
WITHIN GROUPS	412	17.3814	.0422		
TOTAL	413	19.6637			

VARIABLE MAGNESUM
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	12.6935	12.6935	74.075	0
WITHIN GROUPS	414	70.9428	.1714		
TOTAL	415	83.6362			

VARIABLE SULFATE
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	21.0954	21.0954	91.869	0
WITHIN GROUPS	415	95.2946	.2296		
TOTAL	416	116.3900			

VARIABLE FLUORIDE
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	84.1883	84.1883	155.772	.000
WITHIN GROUPS	416	224.8300	.5405		
TOTAL	417	309.0183			

VARIABLE HCO3
BY AQUIF

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	3.7123	3.7123	14.331	.000
WITHIN GROUPS	415	107.5031	.2590		
TOTAL	416	111.2154			

VARIABLE POTASS
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.0170	.0170	.177	.676
WITHIN GROUPS	45	4.3154	.0959		
TOTAL	46	4.3324			

VARIABLE CHLORIDE
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.2680	.2680	1.015	.315
WITHIN GROUPS	180	47.5505	.2642		
TOTAL	181	47.8185			

VARIABLE SULFATE
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.5877	.5877	3.991	.047
WITHIN GROUPS	180	26.5024	.1472		
TOTAL	181	27.0901			

VARIABLE MAGNESUM
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.0338	.0338	.321	.572
WITHIN GROUPS	180	18.9560	.1053		
TOTAL	181	18.9897			

VARIABLE CALCIUM
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.2969	.2969	1.777	.184
WITHIN GROUPS	180	30.0753	.1671		
TOTAL	181	30.3722			

VARIABLE SODIUM
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.0455	.0455	.929	.336
WITHIN GROUPS	180	8.8090	.0489		
TOTAL	181	8.8545			

VARIABLE FLUORIDE
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	5.1426	5.1426	12.124	.001
WITHIN GROUPS	180	76.3475	.4242		
TOTAL	181	81.4901			

VARIABLE HCO3
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.2142	.2142	3.273	.072
WITHIN GROUPS	180	11.7782	.0654		
TOTAL	181	11.9923			

VARIABLE COND
BY METHOD

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	1	.1327	.1327	4.973	.027
WITHIN GROUPS	179	4.7761	.0267		
TOTAL	180	4.9088			

CONTINUOUS HYDROLOGIC DATA SUMMARY STATISTICS

FOR BOX ELDER GULCH NEAR WEST LINE TRACT C-a

	Temperature °C	Flow (cfs)	Specific Conductance (umhos/cm)	Suspended Sediment Load (Tons/day)
Mean	11.312	0.198	775.08	1.750
Standard Error of Mean	0.265	0.019	7.742	0.326
Standard Deviation	2.514	0.588	73.446	4.125
Median	11.15	0.001	784.0	0.085
Mode	9.5	0	871.0	0
Kurtosis	-0.084	9.514	- 0.566	6.866
Skewness	0.091	3.266	0.351	2.755
Maximum	17.5	2.9	891	21.0
Minimum	5.5	0	595	0
95% Limits on Mean				
Upper Limit	11.839	0.236	790.46	2.394
Lower Limit	10.786	0.161	759.69	1.106

CONTINUOUS HYDROLOGIC DATA SUMMARY STATISTICS
FOR CORRAL GULCH NEAR WEST LINE TRACT C-a

	Temperature °C	Flow (cfs)	Specific Conductance (umhos/cm)	Suspended Sediment Load (Tons/day)
Mean	14.82	0.178	1043.1	0.180
Standard Error of Mean	0.36	0.005	7.63	0.035
Standard Deviation	5.97	0.166	114.7	0.945
Median	15.45	0.17	1060	0.011
Mode	11.40	0	1080	0
Kurtosis	- 0.316	0.383	0.074	142.527
Skewness	- 0.204	0.883	- 0.332	10.817
Maximum	33.1	0.74	1330	16.0
Minimum	0.50	0	752	0
95% Limits on Mean				
Upper Limit	15.53	0.189	1058.15	0.248
Lower Limit	14.11	0.168	1028.08	0.111

CONTINUOUS HYDROLOGIC DATA SUMMARY STATISTICS
FOR CORRAL GULCH EAST OF TRACT C-a

	Temperature °C	Flow (cfs)	Specific Conductance (umhos/cm)	Suspended Sediment Load (Tons/day)
Mean	10.20	0.735	1271.48	2.605
Standard Error of Mean	0.118	0.019	9.53	0.549
Standard Deviation	2.517	0.572	187.3	14.84
Median	10.344	0.543	1250	0.097
Mode	8.0	0.58	1250	0.040
Kurtosis	0.436	19.58	1.489	140.16
Skewness	0.420	3.779	0.719	10.88
Maximum	22.0	5.60	2050	240.00
Minimum	5.0	0.060	761	0.01
95% Limits on Mean				
Upper Limit	10.43	0.772	1290	3.68
Lower Limit	9.97	0.698	1252	1.52

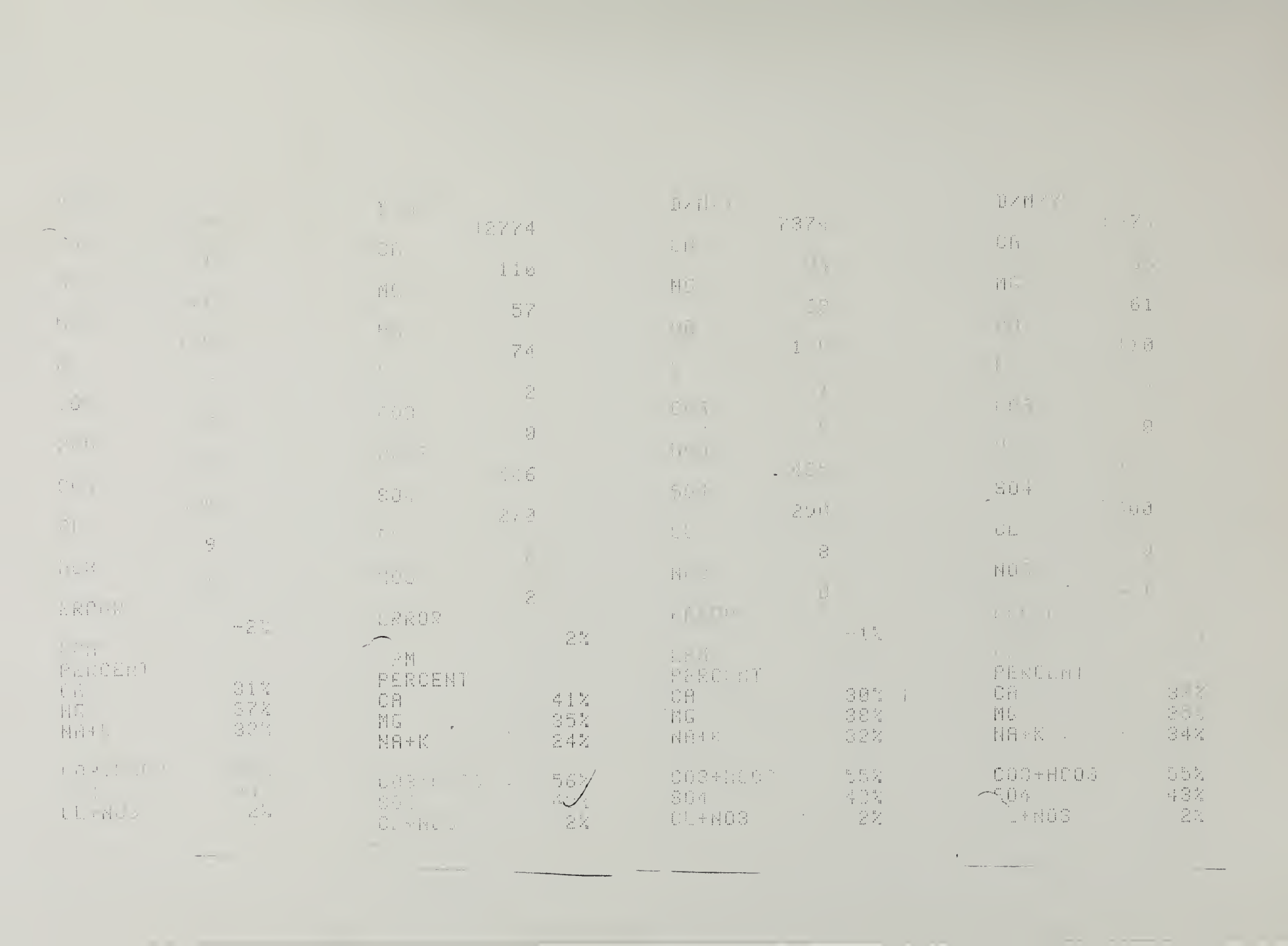
CONTINUOUS HYDROLOGIC DATA SUMMARY STATISTICS
FOR YELLOW CREEK NEAR WHITE RIVER, COLORADO

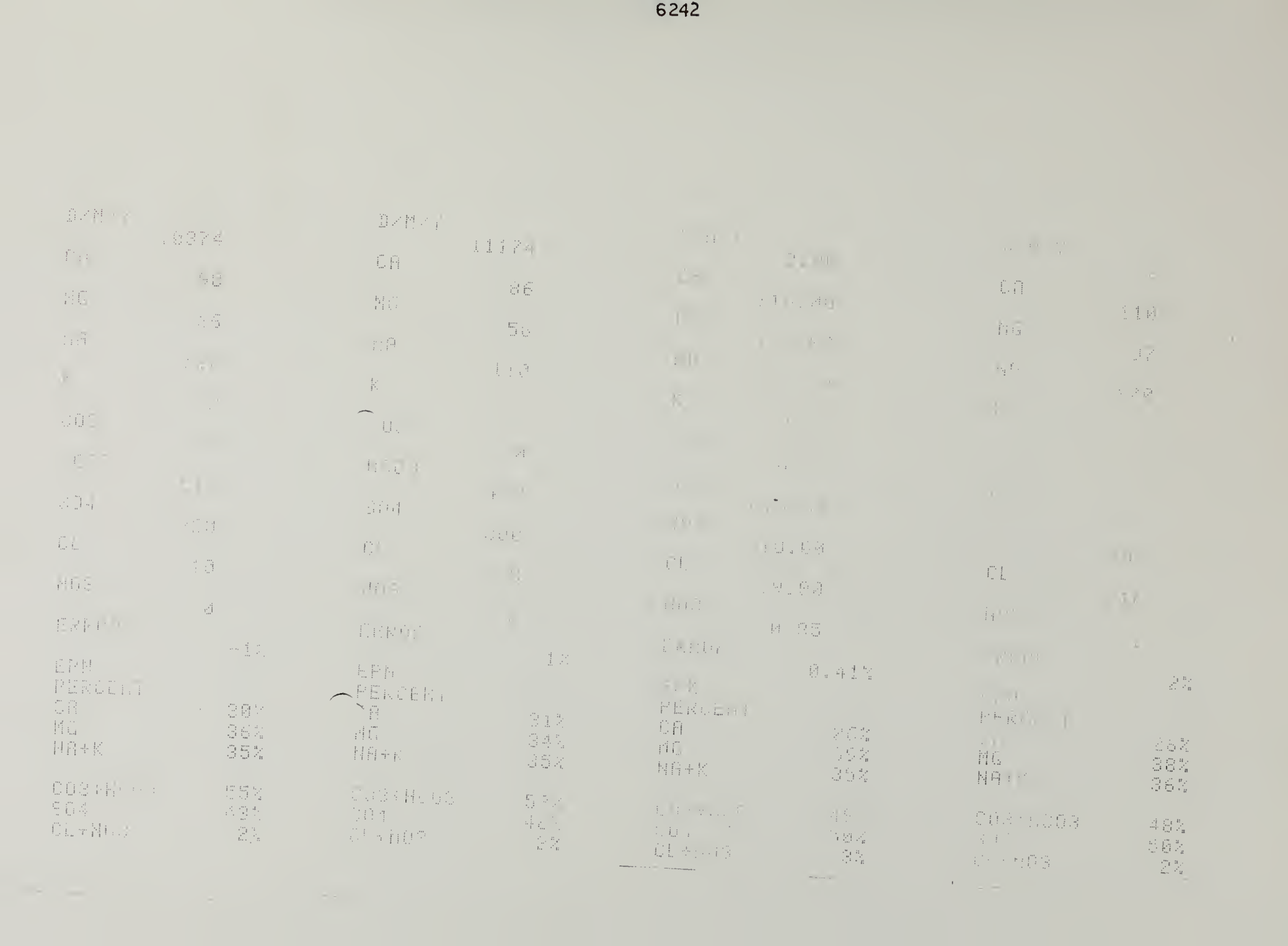
	Temperature °C	Flow (cfs)	Specific Conductance (umhos/cm)	Suspended Sediment Load (Tons/day)
Mean	12.07	1.869	3532	4.71
Standard Error of Mean	0.313	0.042	26.18	1.005
Standard Deviation	6.67	1.306	568.26	30.17
Median	14.03	1.696	3581	0.604
Mode	17.0	1.6	3600	1.50
Kurtosis	- 1.06	26.64	0.758	542.81
Skewness	- 0.41	4.268	- 0.536	21.54
Maximum	25.0	13.0	5080	800.00
Minimum	0	0.23	1410	0.10
95% Limits on Mean				
Upper Limit	12.69	1.95	3583.6	6.687
Lower Limit	11.46	1.78	3480.7	2.741

PERCENT EQUIVALENT PPM
OF MAJOR GROUNDWATER CHEMICAL CONSTITUENTS

6255

USGS STATION NO.





[illegible]	[illegible]
CA	[illegible]
MG	[illegible]
NA	[illegible]
K	[illegible]
NO3	[illegible]
SO4	[illegible]
CL	290.00
HCO3	0.00
ION	1.00
ERROR	0.36%
EPM	
PERCENT	
CA	30%
MG	39%
NA+K	31%
CO3+HCO3	49%
SO4	49%
CL+NO3	2%

[illegible]	[illegible]
CA	[illegible]
MG	96
NA	[illegible]
K	[illegible]
NO3	[illegible]
SO4	[illegible]
CL	278
HCO3	8
ION	1
ERROR	[illegible]
EPM	
PERCENT	
CA	34%
MG	35%
NA+K	[illegible]
CO3+HCO3	[illegible]
SO4	46%
CL+NO3	2%

[illegible]	[illegible]
CA	[illegible]
MG	72
NA	[illegible]
K	[illegible]
NO3	[illegible]
SO4	[illegible]
CL	296
HCO3	5
ION	[illegible]
ERROR	[illegible]
EPM	
PERCENT	
CA	30%
MG	38%
NA+K	32%
CO3+HCO3	50%
SO4	48%
CL+NO3	2%

[illegible]	[illegible]
CA	[illegible]
MG	91
NA	[illegible]
K	[illegible]
NO3	96
SO4	[illegible]
CL	293
HCO3	8
ION	1
ERROR	2%
EPM	
PERCENT	
CA	36%
MG	36%
NA+K	29%
CO3+HCO3	51%
SO4	47%
CL+NO3	2%

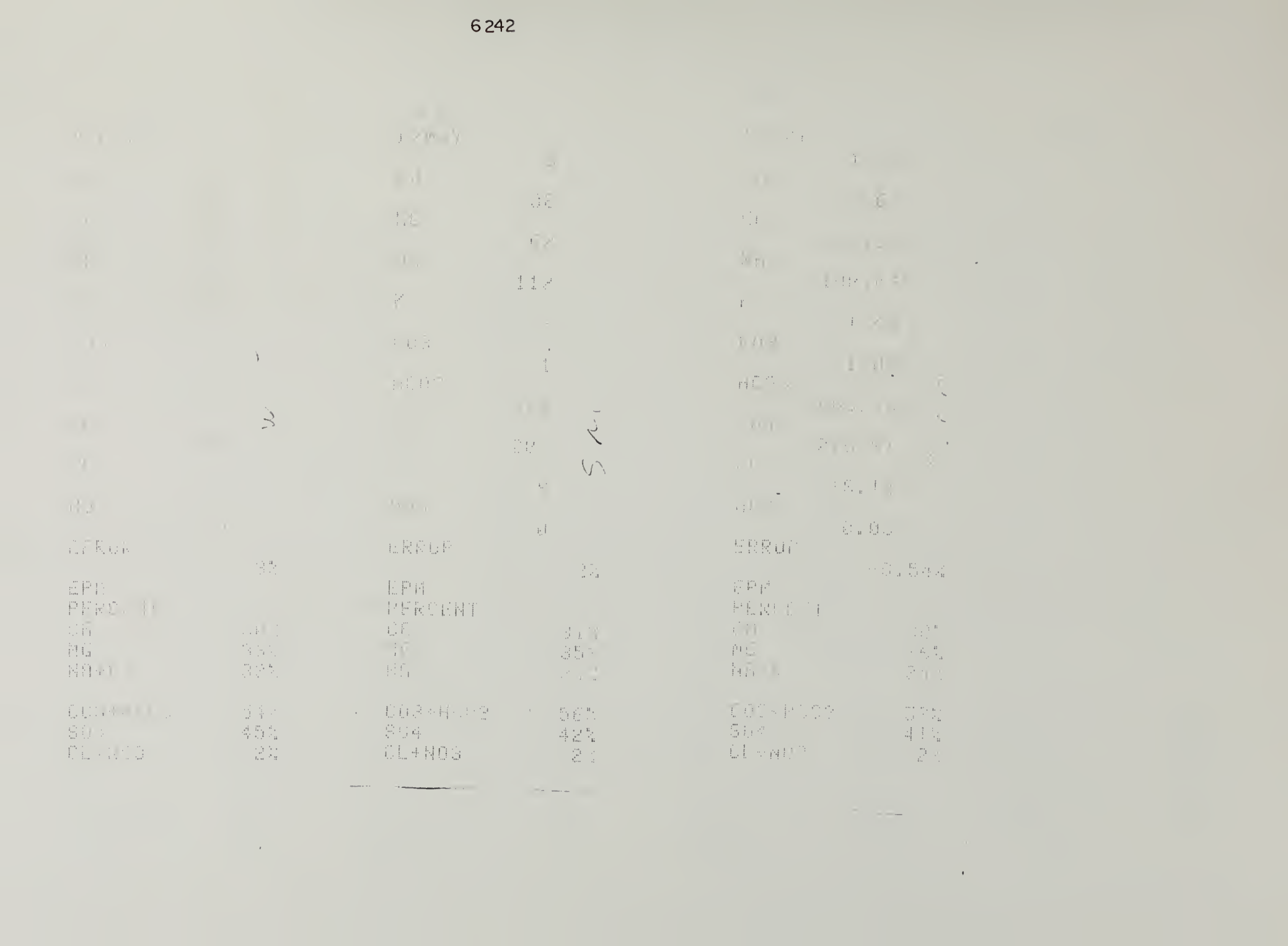
MG		MG	
NA		NA	
K			
CL		CL	8.20
NO3		NO3	2.29
ERROR		ERROR	3 MIN
EPM		EPM	
PERCENT		PERCENT	
CA	33%	CA	39%
MG	37%	MG	36%
NA+K	30%	NA+K	25%
CO3+HCO3	52%	CO3+HCO3	52%
SO4	45%	SO4	46%
CL+NO3	2%	CL+NO3	2%

6235

6240

6242

	6242
	8
	65
	38
	4
	1
	12
	-12%
	.9%
	54%
	43%
	3%



S 7

CL	
EPROR	
	4%
EPM	
PERCENT	
CA	31%
MG	32%
NA+K	37%

S 8

CA	[illegible]
MG	[illegible]
NA	[illegible]
K	[illegible]
SO4	[illegible]
HCO3	[illegible]
CL	16.50
NO3	3.05
ERROR	[illegible]%

EPM PERCENT	
CA	33%
MG	28%
NA+K	39%
CO3+HCO3	59%
SO4	37%
CL+NO3	4%

S 8

D/H-W	2196.00
CA	78.00
MG	70.60
NA	[illegible]
K	[illegible]
CO3	[illegible]
HCO3	[illegible]
SO4	260.00
CL	7.00
NO3	3.00
ERROR	10.59

EPM PERCENT	
CA	29%
MG	46%
NA+K	26%
CO3+HCO3	61%
SO4	37%
CL+K	2%

S 11

D/H-W	5
CA	[illegible]
MG	88
NA	[illegible]
K	[illegible]
CO3	0
HCO3	[illegible]
SO4	350
CL	20
NO3	0
ERROR	6%

EPM PERCENT	
CA	25%
MG	32%
NA+K	43%
CO3+HCO3	43%
SO4	54%
CL+NO	3%

S 11

D/H-W	[illegible]
CA	[illegible]
MG	110.40
NA	[illegible]
K	2.50
CO3	19.80
HCO3	[illegible]
SO4	[illegible]
CL	14.80
NO3	0.70
ERROR	-5.71%

EPM PERCENT	
CA	29%
MG	40%
NA+K	31%
CO3+HCO3	[illegible]%
SO4	[illegible]%
CL+NO3	2%

S 11

NO3	0
ERROR	4%
EPM	
PERCENT	
CA	23%
MG	46%
NA+K	31%
CO3+HCO3	41%
SO4	57%
CL+NO3	1%

S 11

CA	88.00
MG	105.00
CL	5.90
NO3	16.00
ERROR	1.64%
EPM	
PERCENT	
CA	19%
MG	37%
NA+K	44%
CO3+HCO3	43%
SO4	55%
CL+NO3	2%

S 11

MG	96
ERROR	3%
PERCENT	
CA	27%
MG	31%
NA+K	42%
CO3+HCO3	48%
SO4	52%
CL+NO3	3%

S 12

ERROR	4%
CA	23%
MG	45%
NA+K	32%

S 12

[illegible]

[illegible]

[illegible]

SPRINGS

SPRINGS

[illegible]	
[illegible]	
[illegible]	[illegible]
[illegible]	46.00
[illegible]	[illegible]
[illegible]	1.00
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	250.00
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	-3.68%

EPM	
PERCENT	
CA	31%
MG	37%
NA+K	33%
CO3+HCO3	59%
SO4	39%
CL+NO3	2%

D/M/Y	
	3.00
CA	91.00
MG	70.00
NA	120.00
K	2.00
[illegible]	2.00
HCO3	[illegible]
SO4	540.00
CL	12.00
NO3	0.50
ERROR	3.90%

EPM	
PERCENT	
CA	29%
MG	37%
NA+K	34%
CO3+HCO3	56%
SO4	42%
CL+NO3	2%

D/M/Y	
	[illegible]
CA	32.00
MG	35.00
NA	68.00
K	2.00
[illegible]	[illegible]
HCO3	[illegible]
SO4	[illegible]
CL	11.00
NO3	[illegible]
ERROR	-0.31%

EPM	
PERCENT	
CA	32%
MG	35%
NA+K	33%
CO3+HCO3	56%
SO4	42%
CL+NO3	2%

4-5
U. A.

TO 2
U. A.

[illegible]	[illegible]
[illegible]	2376.00
[illegible]	
[illegible]	9.00
[illegible]	
[illegible]	17.00
[illegible]	
[illegible]	5.30
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	1.60
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
NO3	
1.9%	
ERROR	
-0.27%	
EPM	
PERCENT	
CA	2%
MG	9%
NA+K	89%
[illegible]	67%
SO4	30%
CL+N	2%

[illegible]	
2376.00	
CA	
9.00	
MG	
17.00	
[illegible]	
5.30	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
1.60	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
[illegible]	
NO3	
0.00	
ERROR	
-1.94%	
EPM	
PERCENT	
CA	3%
MG	30%
NA+K	67%
CO3+HCO3	63%
SO4	37%
CL+I	3%

[illegible]

[illegible]

CL-

149

[illegible]

[illegible]

NA

[illegible]

K

3

[illegible]

1

[illegible]

[illegible]

SO

[illegible]

[illegible]

[illegible]

[illegible]

0

STLICR?

0

[illegible]

[illegible]

PPM

PERCENT

[illegible]

39%

MG

[illegible]2%

NA[illegible]

34%

CO3+HCO3

44%

SO4

53%

CL+NO3

3%

CA	120
MG	96
NA	103
K	0
CO3	0
HCO3	319
SO4	560
CL	20
NO3	0
SILICA?	0

ERROR 3%

EPM
PERCENT
CA 28%
MG 35%
NA+K 37%

CO3+HCO3 41%
SO4 56%
CL+NO3 3%

CA	6244
MG	120
NA	120
K	194
CO3	0
HCO3	0
SO4	649
CL	530
NO3	25
SILICA?	4

ERROR 4%

EPM
PERCENT
CA 25%
MG 41%
NA+K 35%

CO3+HCO3 45%
SO4 52%
CL+NO3 3%

[illegible]	6235
CA	96
MG	1
[illegible]	96
K	
[illegible]	3
HCO3	407
[illegible]	296
CL	9
NO3	3
SILICA	0

ERROR	3%
EPM	
PERCENT	
CA	34%
MG	37%
NA+K	29%
CO3+HCO3	52%
SO4	47%
CL+NO3	2%

T/M/Y	6235
CA	87
MG	58
NA	85
K	0
CO3	0
HCO3	425
SO4	260
CL	9
NO3	0
SILICA?	0

ERROR	-2%
EPM	
PERCENT	
CA	34%
MG	31%
NA+K	29%
CO3+HCO3	53%
SO4	45%
CL+NO3	2%

D/M/Y	6235
CA	84
MG	60
NA	78
K	0
CO3	0
HCO3	390
SO4	250
CL	9
NO3	0
SILICA?	0

ERROR	5%
EPM	
PERCENT	
CA	32%
MG	33%
NA+K	30%
CO3+HCO3	51%
SO4	47%
CL+NO3	2%

D/M/Y	6235
CA	96
MG	61
NA	81
K	0
CO3	0
HCO3	375
SO4	240
CL	9
NO3	0
SILICA?	0

ERROR	10%
EPM	
PERCENT	
CA	35%
MG	38%
NA+K	27%
CO3+HCO3	52%
SO4	46%
CL+NO3	2%

CA	68
MG	52
NA	30
K	6
CO3	0
HCO3	244
SO4	11
CL	1
NO3	0
SILICA?	3

ERROR 39%

CA	15%
MG	21%
NA+K	64%
CO3+HCO3	61%
SO4	36%
CL+NO3	2%

CA	92
MG	70
NA	111
K	0
CO3	0
HCO3	735
SO4	310
CL	3
NO3	0
SILICA?	0

ERROR -21%

CA	30%
MG	36%
NA+K	32%
CO3+HCO3	64%
SO4	34%
CL+NO3	1%

D/M/Y	6242
CA	80
MG	56
NA	111
K	9
CO3	0
HCO3	174
SO4	260
CL	11
NO3	0
SILICA?	0

ERROR	4%

EPM	
PERCENT	
CA	28%
MG	37%
NA+K	35%
CO3+HCO3	57%
SO4	41%
CL+NO3	2%

D/M/Y	6242
CA	80
MG	56
NA	111
K	9
CO3	0
HCO3	174
SO4	260
CL	11
NO3	0
SILICA?	0

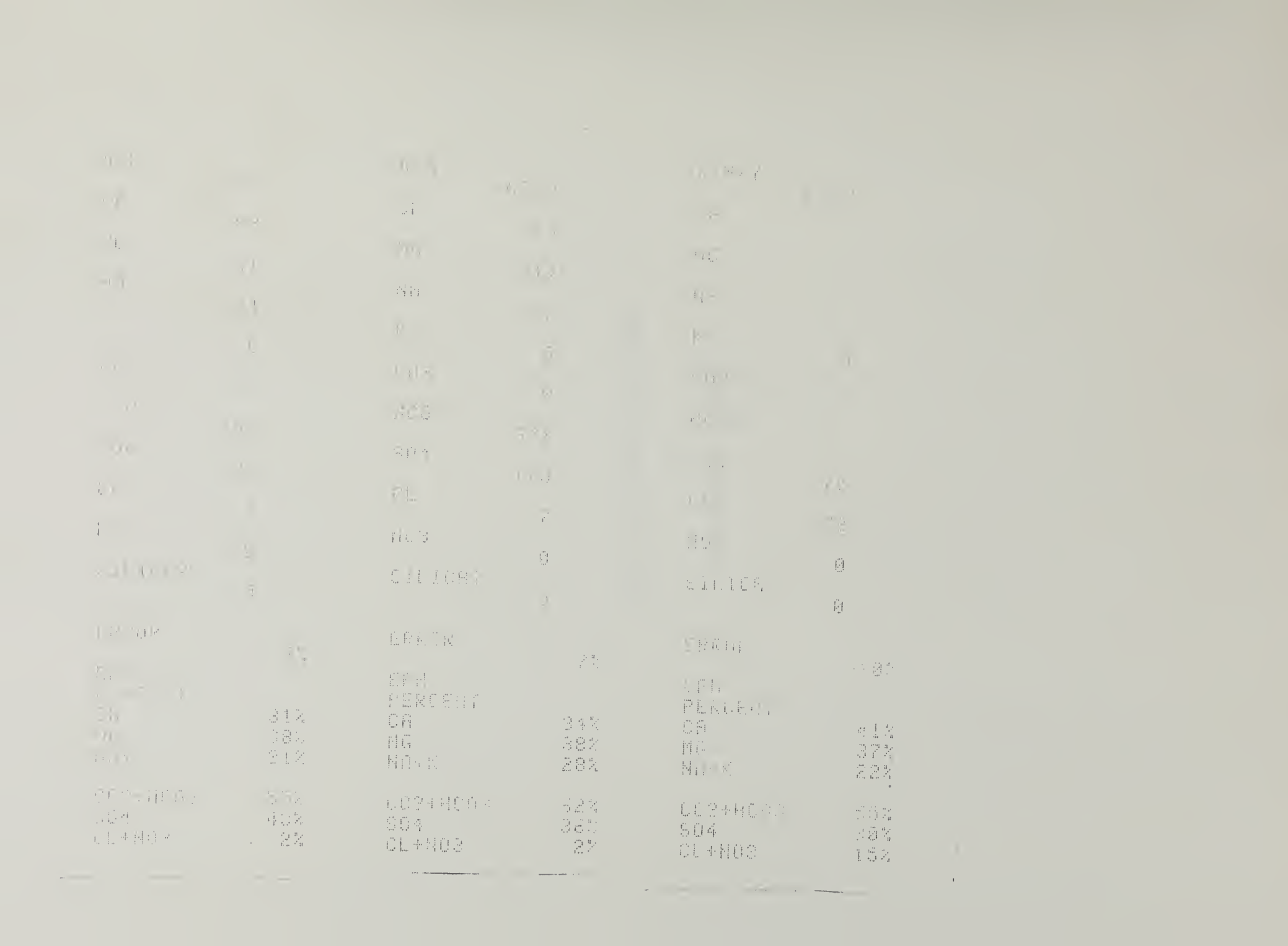
EPROR	4%

EPM	
PERCENT	
CA	28%
MG	34%
NA+K	38%
CO3+HCO3	52%
SO4	47%
CL+NO3	1%

D/M/Y	6242
CA	80
MG	56
NA	111
K	9
CO3	0
HCO3	174
SO4	260
CL	11
NO3	0
SILICA?	0

ERROR	4%

EPM	
PERCENT	
CA	30%
MG	34%
NA+K	36%
CO3+HCO3	58%
SO4	40%
CL+NO3	2%


PERCENT
CA
MG
NA+K
CO3+HCO3
SO4
CL+NO3
PERCENT
CA
MG
NA+K
CO3+HCO3
SO4
CL+NO3
PERCENT
CA
MG
NA+K
CO3+HCO3
SO4
CL+NO3

EXPONENTIAL CURVE FIT

TO

LOWER AQUIFER WATER LEVEL DATA

CE 709
LOWER

X?
69.00
Y?
570.67

X?
99.00
Y?
571.04

X?
131.00
Y?
572.19

X?
147.00
Y?
572.53

X?
315.00
Y?
573.00

A0
A1
497.93
53.64

COEFFICIENT
OF DETERMINATION
0.99
CORRELATION
COEFFICIENT
(R)
0.99

ERROR EST OF
Y ON X
0.31

OBSERVED Y
568.13

PREDICTED Y
568.95

RESIDUAL
-0.25

OBSERVED Y
570.67

PREDICTED Y
570.48

RESIDUAL
0.19

AT X =
1089.00

OBSERVED Y
571.04

PREDICTED Y
570.91

RESIDUAL
0.13

AT X =
1131.00

OBSERVED Y
572.19

PREDICTED Y
571.79

RESIDUAL
0.40

AT X =
1147.00

OBSERVED Y
572.53

PREDICTED Y
572.12

.41

CE 709
LOWER

AT X
1215.00

OBSERVED Y
573.00

PREDICTED Y
573.46

RESIDUAL
-0.46

AT X =
1252.00

OBSERVED Y
573.81

PREDICTED Y
574.16

RESIDUAL
-0.35

AT Y =
1280.00

OBSERVED Y
574.78

PREDICTED Y
574.67

AT X
1341.00

OBSERVED Y
575.77

PREDICTED Y
575.76

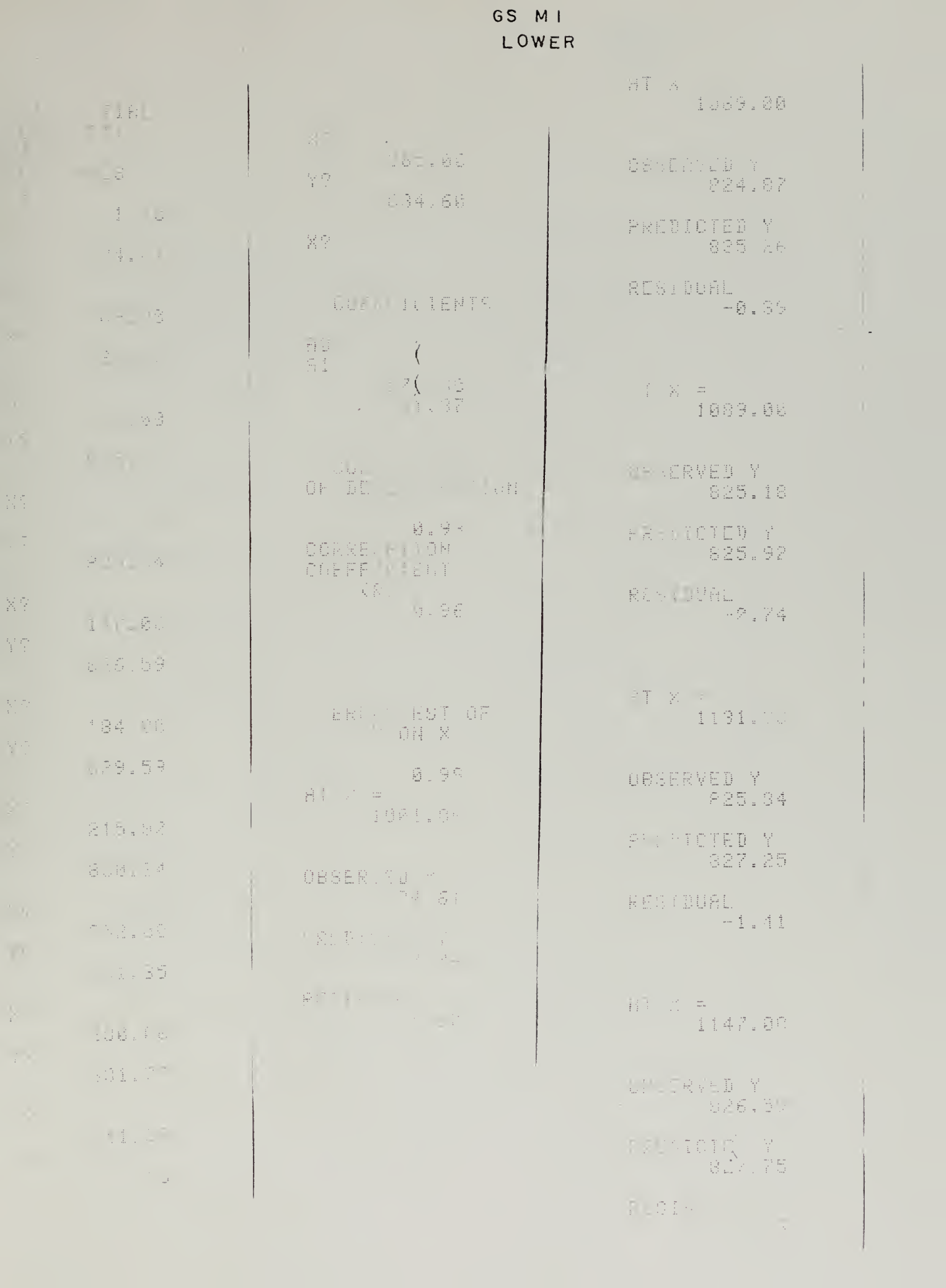
RESIDUAL
0.01

OBSERVED Y
576.22

PREDICTED Y
576.17

RESIDUAL
.05

GS MI
LOWER



GS MI
LOWER

AT X =
1134.00

OBSERVED Y
829.59

PREDICTED Y
828.87

RESIDUAL
0.72

AT X =
1215.00

OBSERVED Y
830.34

PREDICTED Y
829.78

RESIDUAL
0.56

AT X =
1358.00

OBSERVED Y
831.95

PREDICTED Y
830.04

RESIDUAL
1.91

AT X =
[illegible] 0.00

OBSERVED Y
831.79

PREDICTED Y
831.63

RESIDUAL
0.16

AT X =
1241.00

OBSERVED Y
832.65

PREDICTED Y
833.27

RESIDUAL
-0.62

AT X =
1355.00

OBSERVED Y
[illegible] .00

PREDICTED Y
833.08

RESIDUAL
0.72

TO 2
LOWER

AT X =
1069.

OBSERVED Y
359.62

PREDICTED Y
359.56

RESIDUAL
0.06

AT X =
1089.00

OBSERVED Y
359.96

PREDICTED Y
360.12

RESIDUAL
-0.17

AT X =
1131.00

OBSERVED Y
361.01

PREDICTED Y
361.27

RESIDUAL
-0.23

TO 2
LOWER

AT X =
1184.00

OBSERVED Y
362.[illegible]

PREDICTED Y
362.66

RESIDUAL
0.27

AT X =
1213.00

OBSERVED Y
363.57

PREDICTED Y
363.45

RESIDUAL
0.12

AT X =
[illegible]

AT X =
1241.00

OBSERVED Y
365.30

PREDICTED Y
366.45

RESIDUAL
-0.86

AT X =
1345.00

OBSERVED Y
366.30

PREDICTED Y
366.38

RESIDUAL
.12

CE 702
LOWER

AT X =
1023.00

OBSERVED Y
41.25

PREDICTED Y
41.73

RESIDUAL
-0.48

AT X =
1069.00

OBSERVED Y
43.00

PREDICTED Y
42.95

RESIDUAL
0.05

AT X =
1009.00

OBSERVED Y
43.41

PREDICTED Y
(.47

AT X =
1131.00

OBSERVED Y
44.21

PREDICTED Y
44.52

CE 702
LOWER

AT X =
1107.00

OBSERVED Y
44.64

PREDICTED Y
44.91

RESIDUAL
-0.27

AT X =
1104.00

OBSERVED Y
45.81

PREDICTED Y
45.80

RESIDUAL
0.01

AT X =
1215.00

OBSERVED Y
48.50

PREDICTED Y
46.52

RESIDUAL
1.98

AT X =
1292.00

OBSERVED Y
47.30

PREDICTED Y
47.37

RESIDUAL
-.07

AT X =
1208.00

OBSERVED Y
[illegible]

PREDICTED Y
47.97

RESIDUAL
-0.07

AT X =
1341.00

OBSERVED Y
48.93

PREDICTED Y
49.27

RESIDUAL
-0.20

AT X =
1365.00

OBSERVED Y
49.10

PREDICTED Y
49.77

RESIDUAL
[illegible]

HISTOGRAMS
GROUNDWATER CHEMICAL CONSTITUENTS

Na

U.A.

Na

U.A.

Ca

U. A.

Ca

U.A.

SiO_2

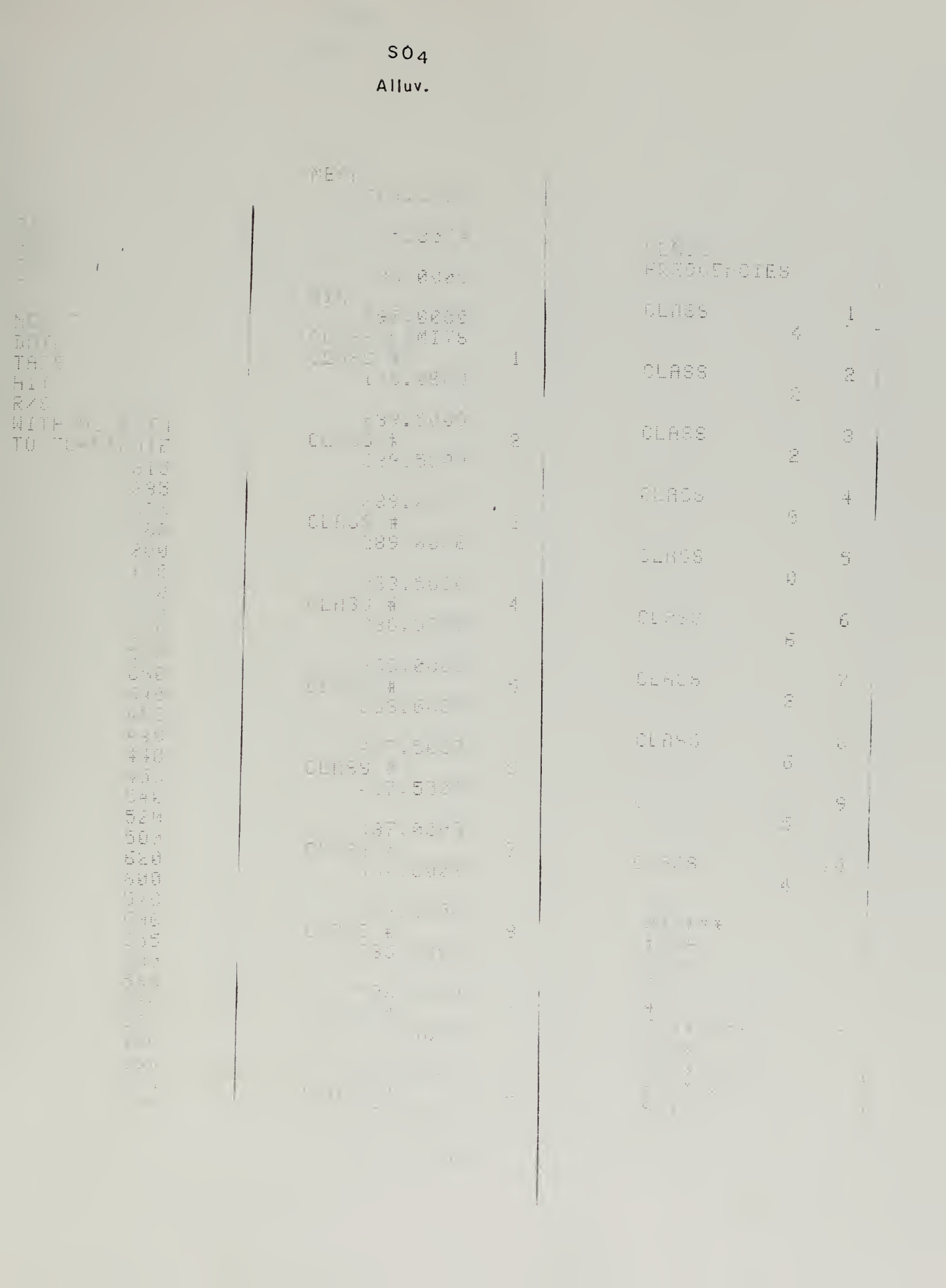
U. A.

Ca

Alluv.

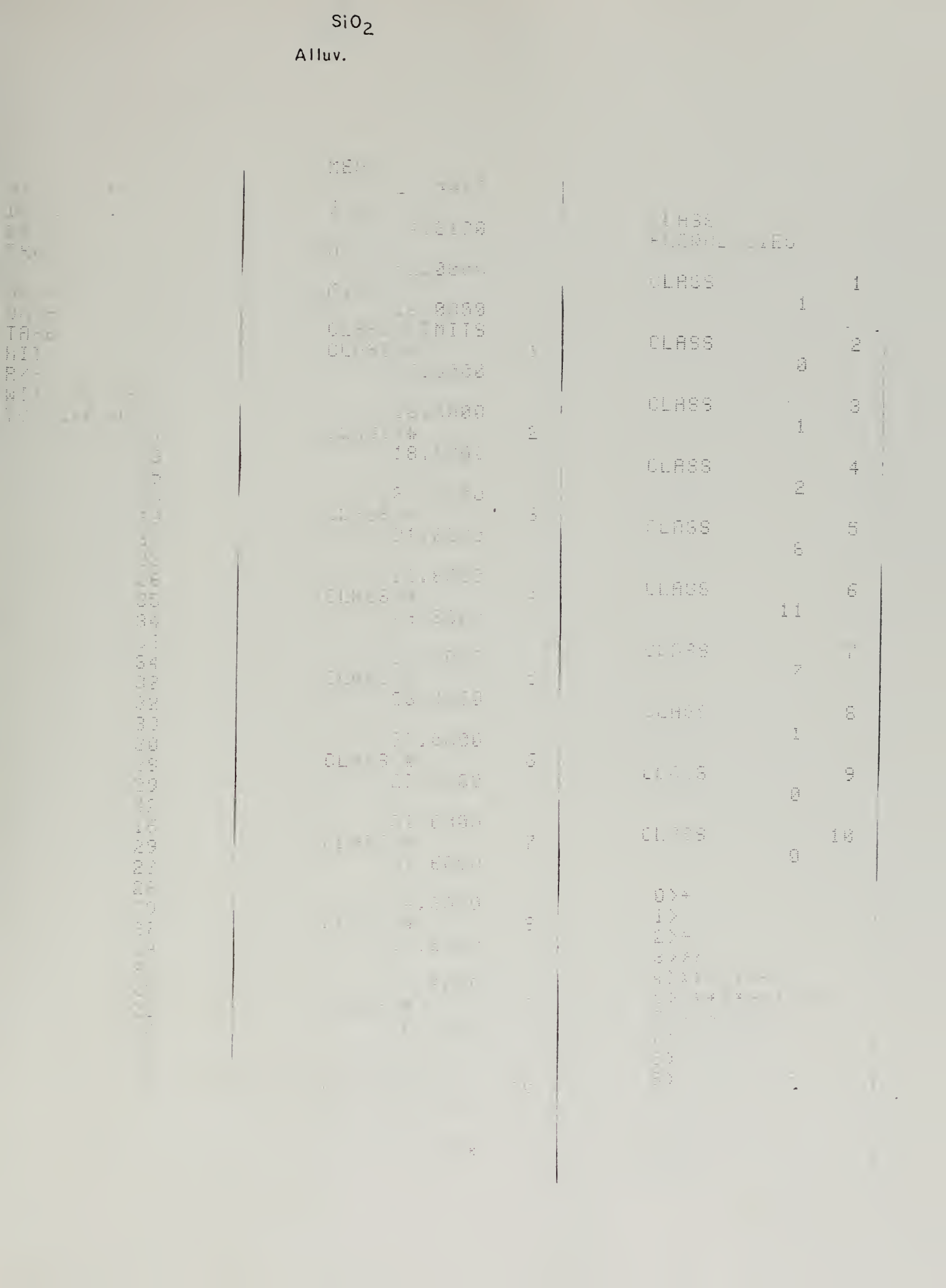
SO_4

Alluv.


CLASS 1
CLASS 2
CLASS 3
CLASS 4
CLASS 5
CLASS 6
CLASS 7
CLASS 8
CLASS 9

SiO_2

Alluv.



Na
Alluv.

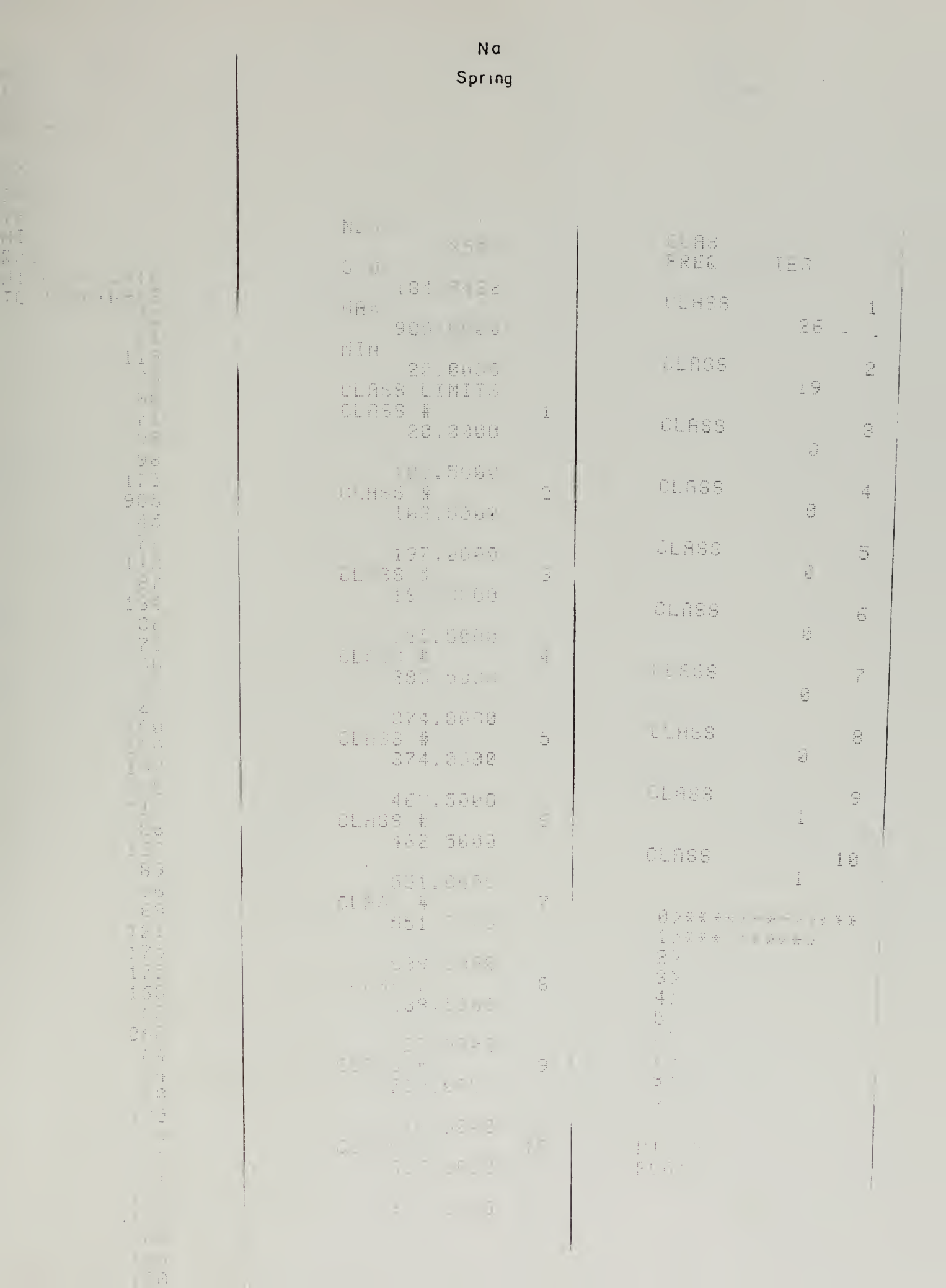
Na
Alluv.

CLASS
FREQUENCIES

CLASS	1
	2
CLASS	2
	2
	3
	0
	4
	1
CLASS	5
	1
CLASS	6
	2
	7
	13
	8
	9
	5
	6
	10
	1

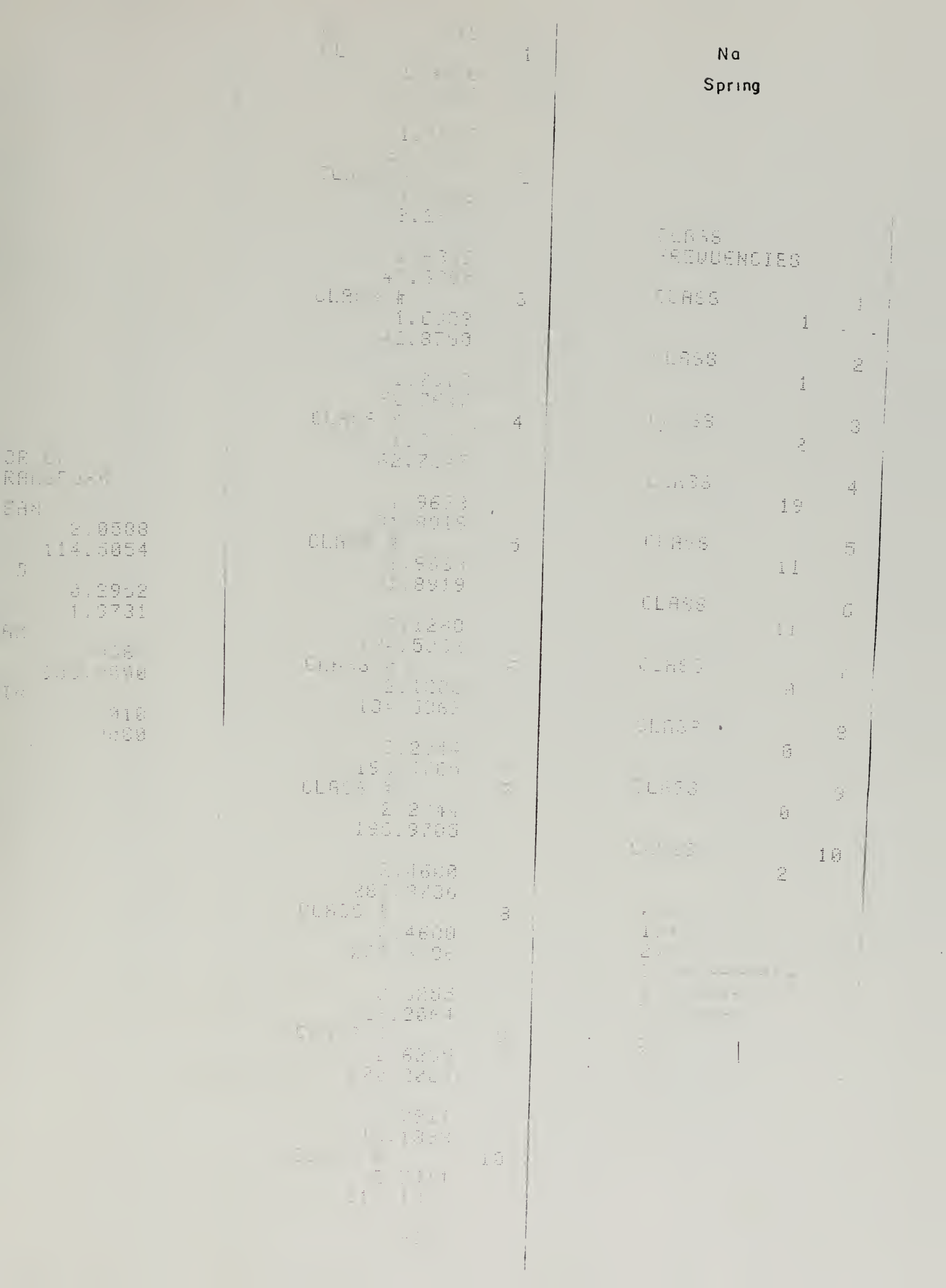
Na

Spring



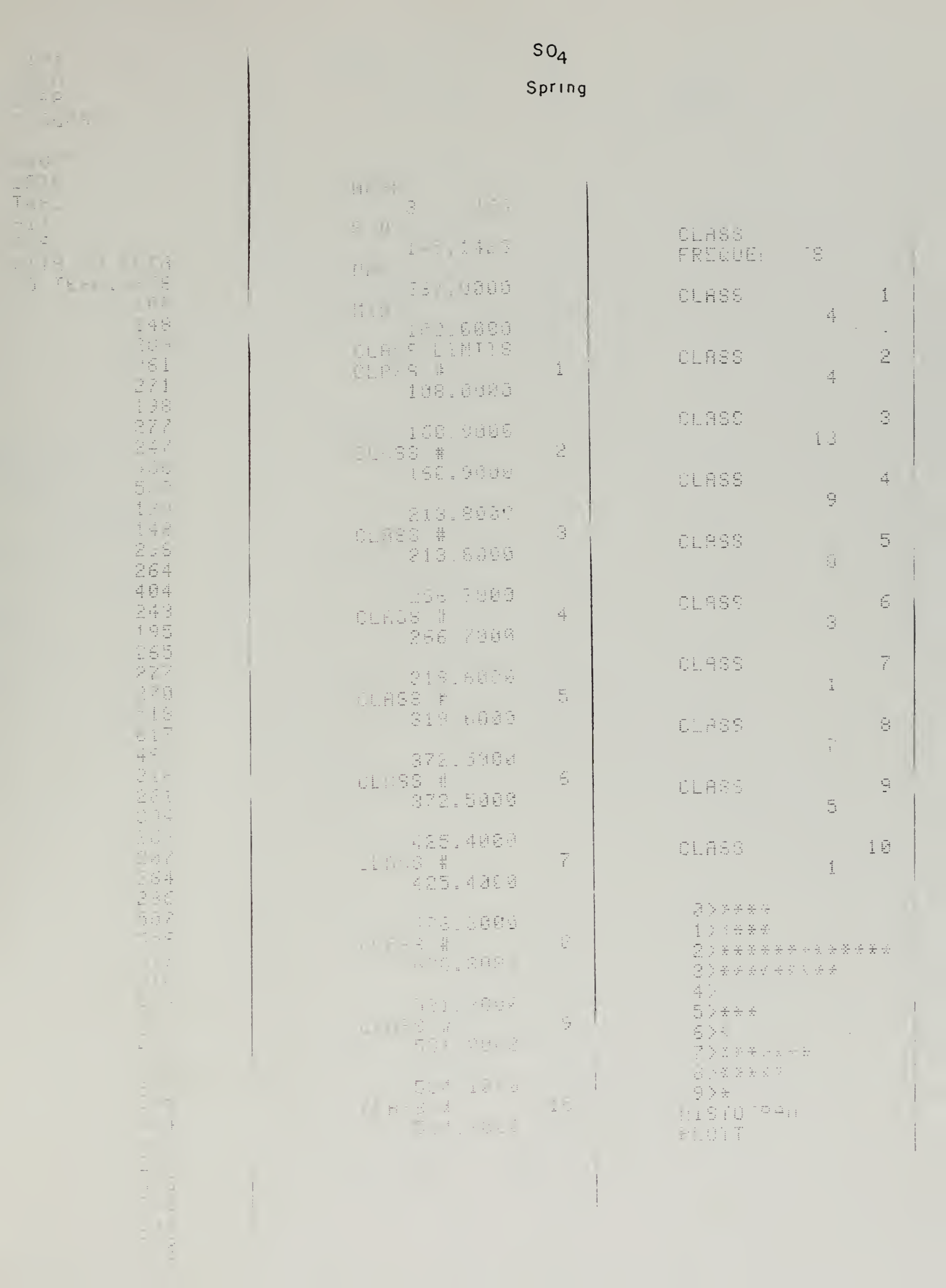
Na

Spring

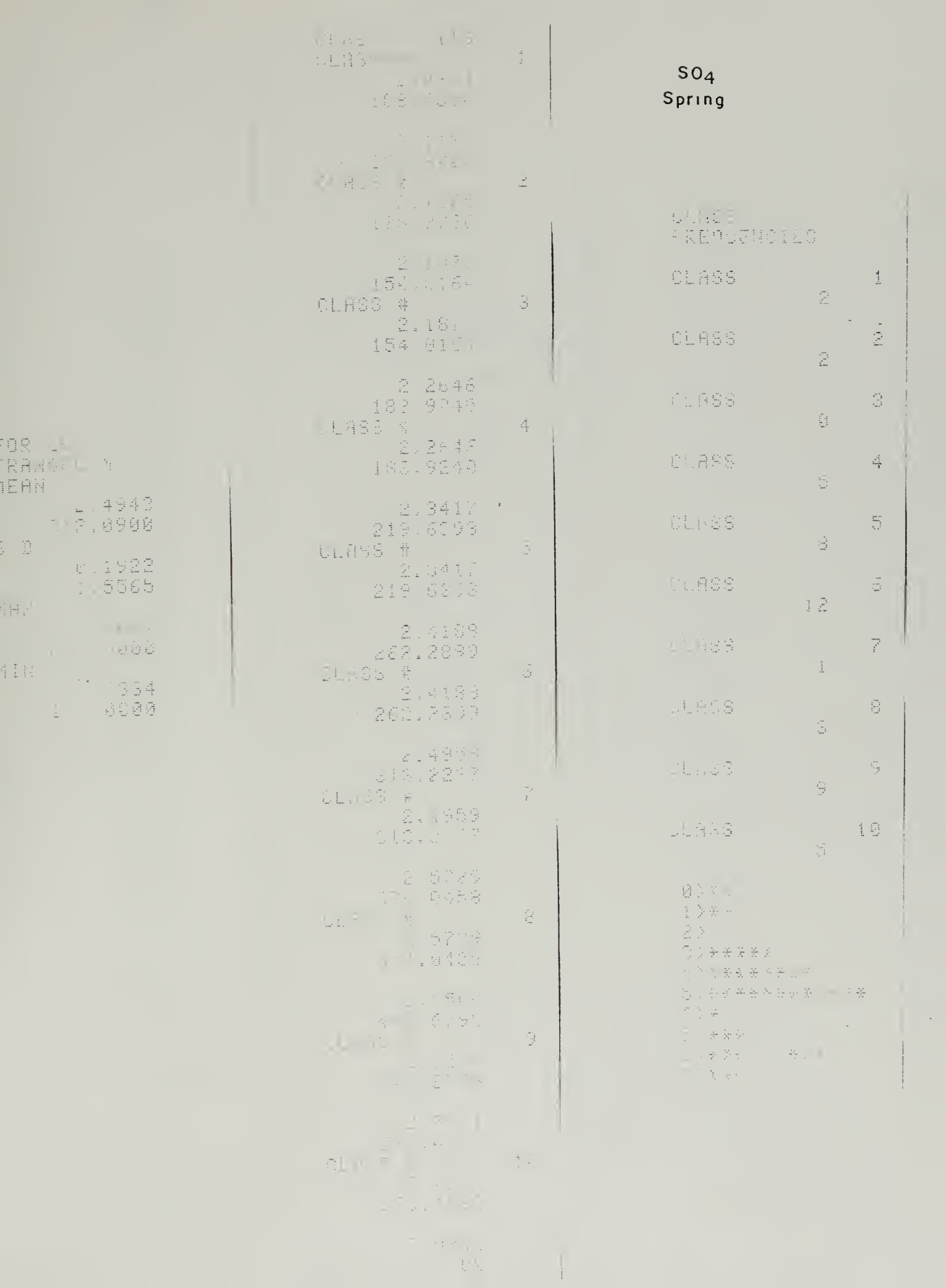


SO_4

Spring

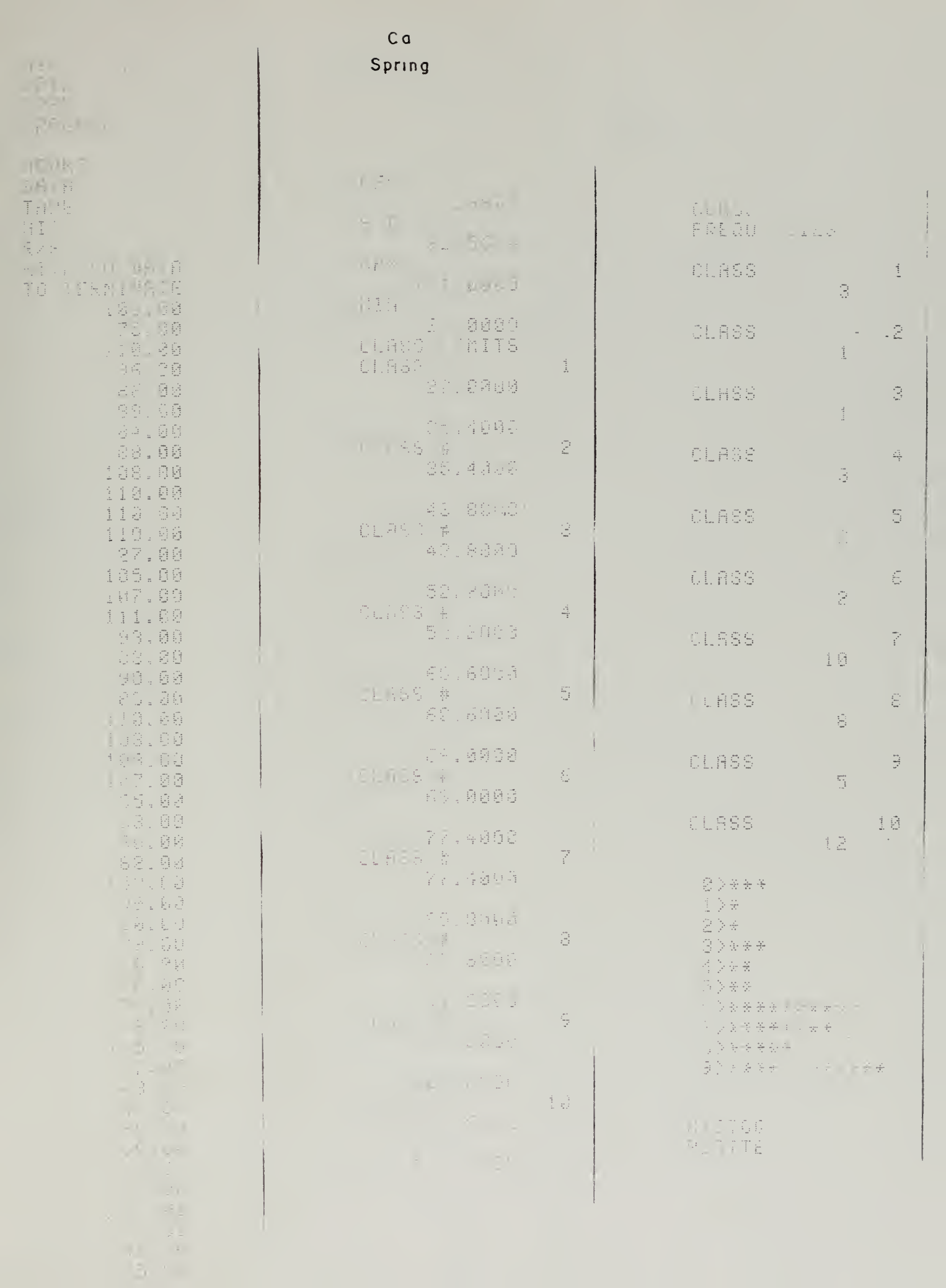

CLASS
FREQUE
CLASS 1
CLASS 2
CLASS 3
CLASS 4
CLASS 5
CLASS 6
CLASS 7
CLASS 8
CLASS 9
CLASS 10
EDIT

SO_4
Spring



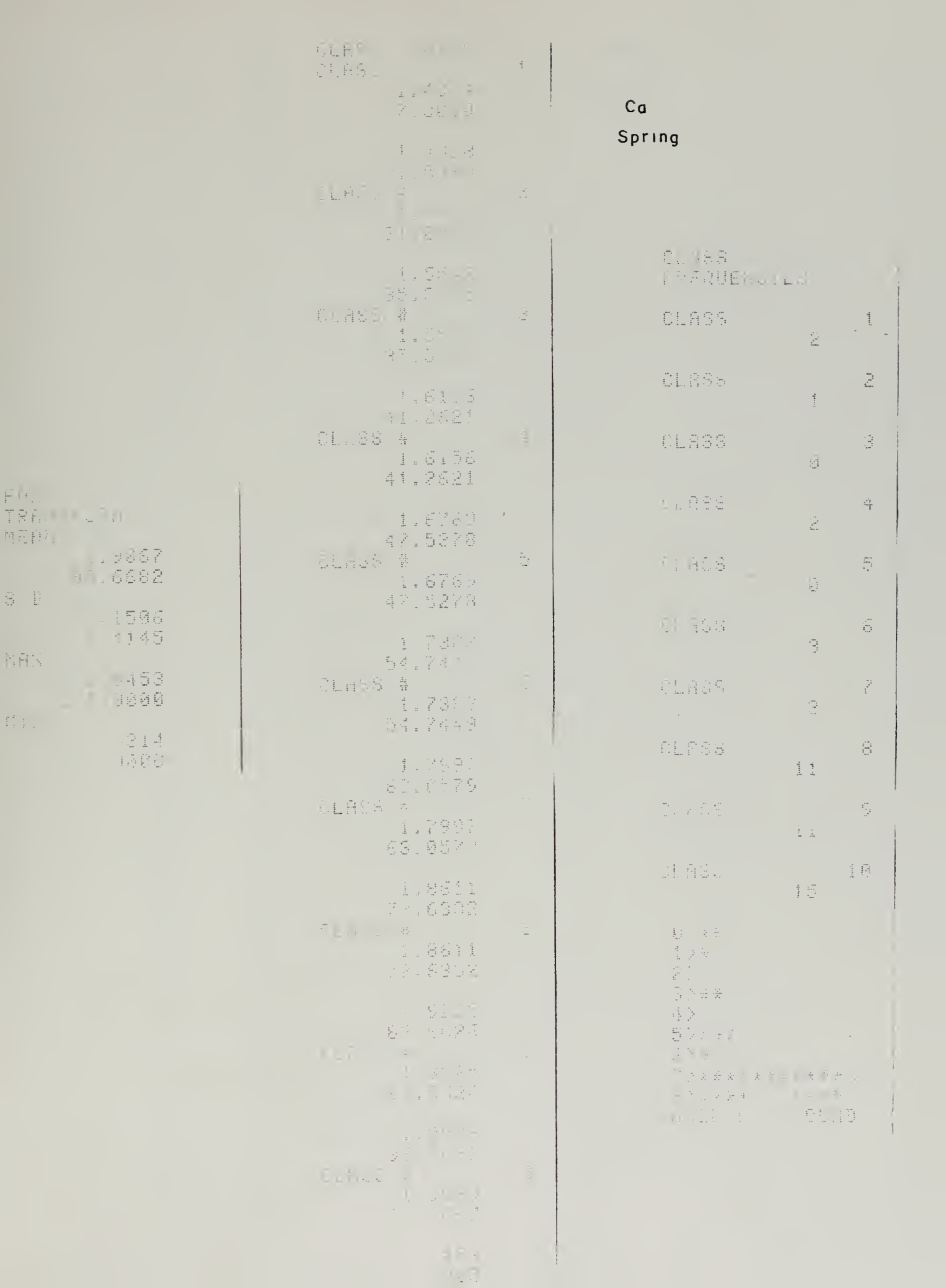
Ca

Spring



Ca

Spring



SiO_2

Spring

CLASS FREQUENCIES

CLASS 1	2
CLASS 2	1
CLASS 3	0
CLASS 4	2
CLASS 5	1
CLASS 6	1
CLASS 7	2
CLASS 8	0
CLASS 9	27
CLASS 10	2

0>*
1>*
2>
3>*
4>*
5>*
6>*
7>****

LABEL NOT FOUND

PLOTTING
PLOTTED

SiO_2

Spring

CLASS FREQUENCIES

CLASS 1	1
CLASS 2	1
CLASS 3	1
CLASS 4	0
CLASS 5	1
CLASS 6	2
CLASS 7	0
CLASS 8	3
CLASS 9	0
CLASS 10	10

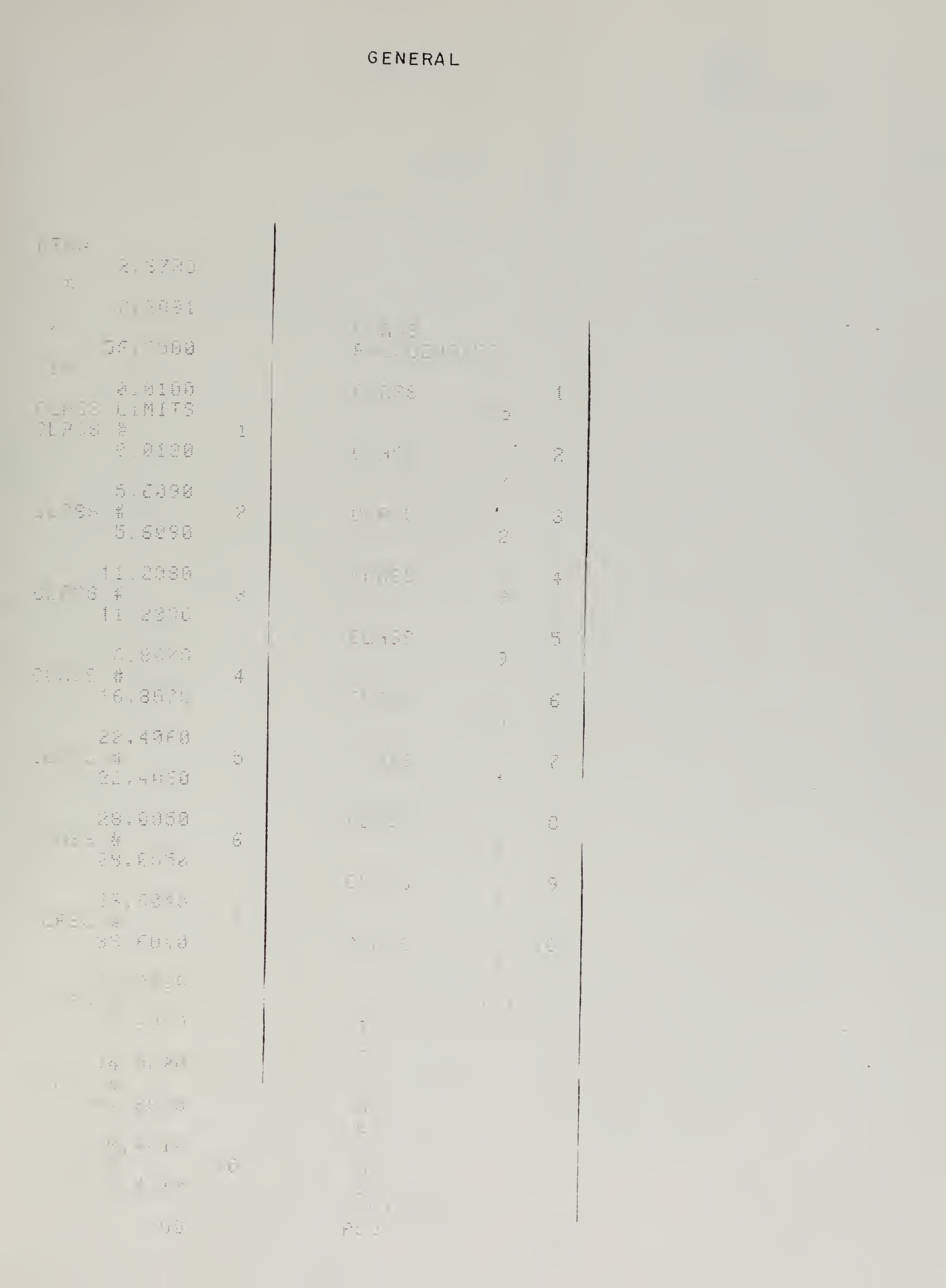
SURFACE WATER

INSTANTANEOUS TOTAL DISSOLVED SOLIDS

Versus

CONDUCTIVITY

LINEAR REGRESSION



6242
USGS
STATION NO.

CLASS
FREQUENCIES

CLASS 1
9

CLASS 2
88

CLASS 3
45

CLASS 4
55

CLASS 5
25

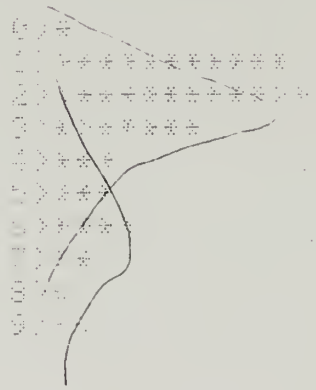
CLASS 6
23

CLASS 7
33

CLASS 8
14

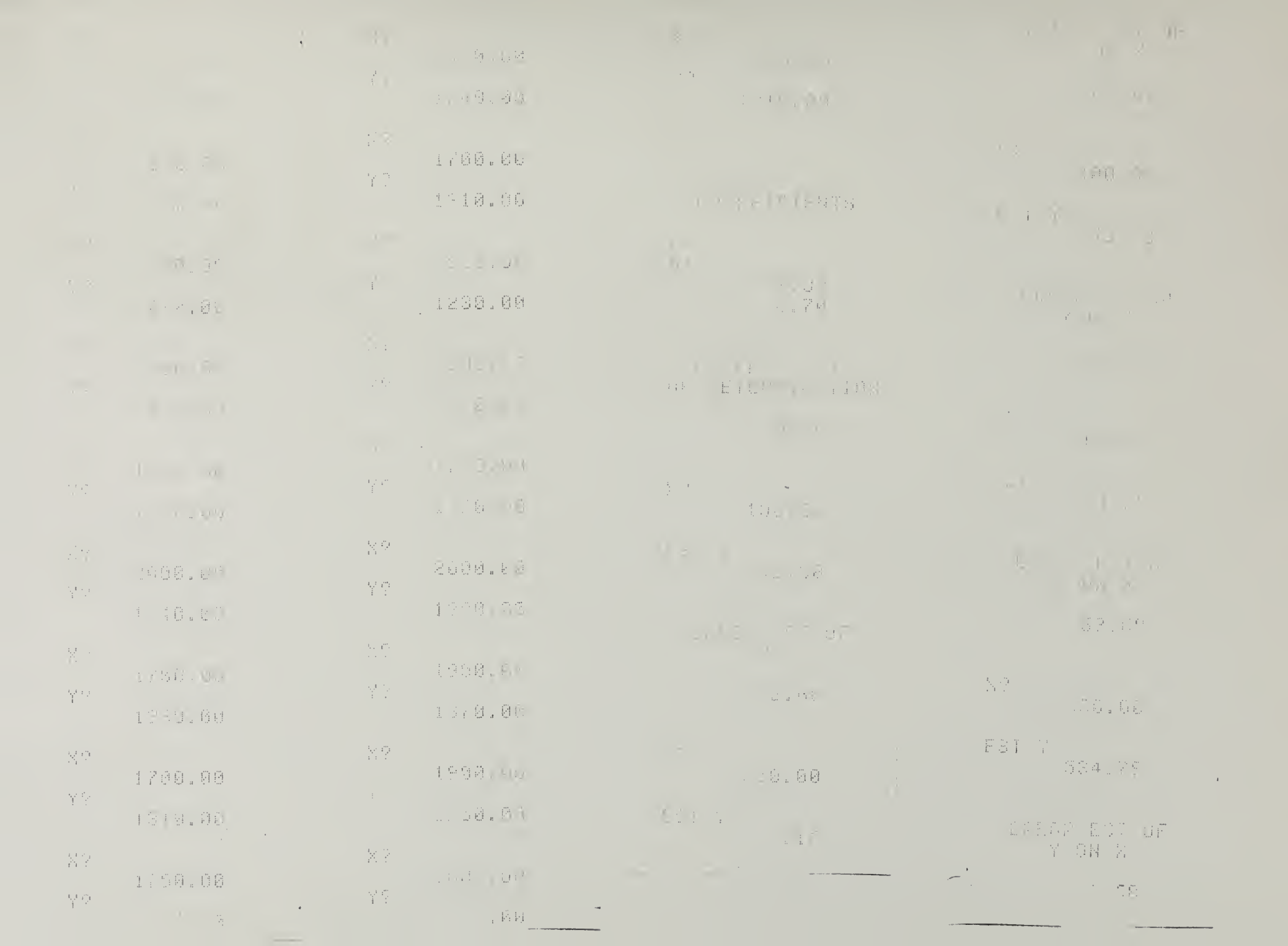
CLASS 9
9

CLASS 10
13



X?
1550.00
Y?
1040.00
X?
1000.00
Y?
.00
X?
1550.00
Y?
1020.00
X?
1100.00
Y?
691.00
X?
1200.00
Y?
734.00
X?
1150.00
Y?
X?
1100.00
Y?
934.00
X?
1305.00
Y?
X?
1250.00
Y?
00

X?
1100.00
Y?
703.00
X?
1050.00
Y?
601.00
X?
1050.00
Y?
702.00
X?
1050.00
Y?
0
X?
1030.00
Y?
728.00
X?
1150.00
Y?
874.00
X?
1030.00
Y?
729.00
X?
1100.00
Y?
0
X?
925.00
Y?
705.00
X?
1150.00
Y?
702.00
X?
1090.00
Y?
0
Y?
707.00
Y?
104.00
Y?
143.00
Y?
220.00
Y?
95.00
Y?
102.00
Y?


1700.00
1250.00
Y?
X?
Y?
X?
Y?
X?

X1
Y1
X2
Y2
X3
Y3
X4
Y4
X5
Y5
X6
Y6
X7
Y7
X8
Y8
X9
Y9
X10
Y10
X11
Y11
X12
Y12
X13
Y13
X14
Y14
X15
Y15
X16
Y16
X17
Y17
X18
Y18
X19
Y19
X20
Y20

X?
1150.00
Y?
725.00

X?
1150.00
Y?
729.00

X?
1100.00
Y?
719.00

X?
1150.00
Y?
756.00

X?
1100.00
Y?
0

6240

6250

6242

Form 1279–3
(June 1984)

BORROWER'S CA

TN 827 .C64 1984 r
test 1+2 app
Progress report ...

DATE LOANED	BORROWER

USDI – BLM